Erfüllung d. Art. 16

VOLUME XIV. PART II.

ENCYCLOPÆDIA BRITANNICA,

OR A

DICTIONARY

OF

ARTS, SCIENCES, AND MISCELLANEOUS LITERATURE.

SEVENTH EDITION,

GREATLY IMPROVED,

WITH THE SUPPLEMENT TO THE FORMER EDITIONS INCORPORATED.

ILLUSTRATED BY AN ENTIRELY NEW SET OF ENGRAVINGS ON STEEL.

EDITED BY PROFESSOR NAPIER.

PRINTED FOR ADAM AND CHARLES BLACK, EDINBURGH;
SIMPKIN, MARSHALL, & CO., WHITTAKER, TREACHER, & CO.,
AND HAMILTON, ADAMS, & CO. LONDON;
AND JOHN CUMMING, DUBLIN.

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On the Maximum Effect of Machines.

P = the pressure exerted by the power at the impelled point of the machine.

R = the pressure which the resistance arising from the work to be performed exerts at the working point of the machine.

a = the inertia of the power P, or the quantity of matter to which it must communicate the velocity of the impelled point.

b = the inertia of the resistance R, or the quantity of matter which it must move with the velocity of the working point before any work is performed.

φ = a quantity of matter which, if placed at the working point of the machine, would oppose the same resistance to the moving power as that which arises from the friction of the communicating parts.

m = the quantity of matter which, if placed at the working point of the machine, would oppose the same resistance to the production of an angular motion, that is opposed by the inertia of the various parts of which the machine is composed. Hence, by the principles of rotation, we have

my^2 = the momentum of inertia of the machine.

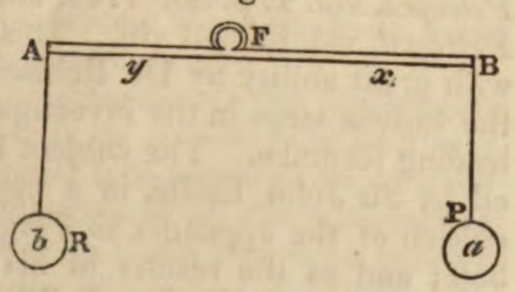
We are now prepared for determining the conditions of construction which will enable any machine to produce a maximum effect.

Prop. I.

To determine the velocities which must be given to the impelled and working points of a machine, or the ratio of the levers by which the power and resistance ought to act, in order to obtain a maximum effect.

Let AB be a lever, whose fulcrum is F, and to whose extremity B is applied the power P to overcome the resistance R, and let FB = x, and FA = y. Then we shall have, from the following analogy, the weight which, placed at B, would be in equilibrio with R; $x : y = R : \frac{Ry}{x}$, the weight which will keep R in equilibrio, or the weight which is equal to that part of the power P which balances the resistance R. Hence, $P - \frac{Ry}{x}$ will be the effective force exerted by the power P, which, multiplied by x, its distance from the centre of motion, gives $Px - Ry$ for the force which is exerted in giving an angular motion to the power and resistance. But the resistance of friction was supposed equal to the weight φ acting at the working point, or at the distance FA or y; consequently, φy will be the resistance which friction opposes to the force $Px - Ry$, and therefore $Px - Ry - \varphi y$ is the motive force exerted by P. Now, the momentum of the inertia of the power P, or the force with which it resists being put in motion, is ax^2, and the momentum of inertia of the resistance R is by^2, while the momentum of inertia of the machine is my^2. Therefore, the sum of these momenta, viz. $ax^2 + by^2 + my^2$ is the mass to be put in motion by the power P. But the velocity generated in a given time is directly as the motive force, and inversely as the quantity of matter to which that force is applied. Hence the angular velocity, or the number of turns which the machine will make in a given time,

Fig. 91.



is $\frac{Px - Ry - \varphi y}{ax^2 + by^2 + my^2}$. But in every rotatory machine the velocities of its different parts are as their distance from the axis; hence we shall have the velocities of the impelled and working points of the machine, by multiplying the angular velocity by x, y, the distances of the impelled and working points of the machine from the centre of motion. Therefore,

$\frac{Px^2 - Rxy - \varphi xy}{ax^2 + by^2 + my^2}$ = the velocity of the impelled point, and

$\frac{Pxy - Ry^2 - \varphi y^2}{ax^2 + by^2 + my^2}$ = the velocity of the working point of the machine; and multiplying by R, we have, from Def. 4,

$\frac{PxyR - R^2y^2 - \varphi Ry^2}{ax^2 + by^2 + my^2}$ = the work performed.

But as forces are proportional to the velocities generated by them in equal times, the preceding quantities will represent the accelerating forces. Now, the velocities are as the forces and times jointly; that is, $v \doteq Ft$, or is $= gtF$; but F, the accelerating force, which generates the velocity of the impelled point, is represented by the formula $\frac{Px^2 - Rxy - \varphi xy}{ax^2 + by^2 + my^2}$. Therefore v, or the absolute velocity of the impelled point, is $\frac{Px^2 - Rxy - \varphi xy}{ax^2 + by^2 + my^2} \times gt$, and the absolute velocity of the working point $\frac{Pxy - Ry^2 - \varphi y^2}{ax^2 + by^2 + my^2} \times gt$. Again, by Def. 4, the effect of a machine, or the work performed, is equal to the resistance of the work multiplied by the velocity; consequently, since R is the work, we have for the performance of the machine,

$$\frac{PxyR - R^2y^2 - \varphi Ry^2}{ax^2 + by^2 + my^2} \times gt.$$

Now, considering y as the variable quantity, and making the fluxion of the preceding formula = 0, we shall find that the performance of the machine is a maximum, when

$$y = \frac{\overline{|a^2 \times R + \varphi|^2 + P^2 a \times m + b|}^{\frac{1}{2}} - aR - a\varphi}{Pm + Pb} \times x.$$

When R = 0, we have

$$y = \frac{\overline{a^2\varphi^2 + P^2 a \times m + b|}^{\frac{1}{2}} - a\varphi}{Pm + Pb} \times x.$$

When φ = 0, the first formula becomes

$$y = \frac{\overline{a^2R^2 + P^2 a \times m + b|}^{\frac{1}{2}} - aR}{Pm + Pb} \times x.$$

When both R and φ = 0, we have, after reduction,

$$y = \frac{\sqrt{a}}{\sqrt{m + b}} \times x.$$

When b = 0, the first formula becomes

$$y = \frac{\overline{a^2 \times R + \varphi|^2 + P^2 am|}^{\frac{1}{2}} - aR - a\varphi}{Pm} \times x.$$

When R, φ, and b = 0, we have

$$y = \frac{\sqrt{a}}{\sqrt{m}} \times x.$$

When $a : b = P : R$, we have, by substituting P and R instead of a and b,

$$y = \frac{\overline{P^2 \times R + \varphi|^2 + P^3 \times m + R|}^{\frac{1}{2}} - PR - P\varphi}{Pm + PR} \times x.$$

When Pm and φ = 0, the last formula becomes

$$y = \frac{\overline{P^2R^2 + P^3R|}^{\frac{1}{2}} - PR}{PR} \times x = \sqrt{\frac{P^2R^2 + P^3R}{P^2R^2}} - \frac{PR}{PR} \times x.$$

$$x = \sqrt{\frac{P}{R} + 1} - 1,$$

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and when $x=1$, and $R=1$, we have

$$y=\sqrt{P+1}|-1;$$

and when $P=1$, and $x=1$, we obtain

$$y=\sqrt{\frac{1}{R}+1}|-1.$$

When $x=1$,

$$y=\sqrt{\frac{1}{R}+1}|-1.$$

These various formulæ, the application of which to particular cases will be shown in the practical part of this article, give us values of y for almost every species of machinery; so that the mechanic may easily determine the velocities which must be given to the impelled and working points of the machine in order to produce a maximum effect.

When the machine, however, is already constructed, the velocities of the impelled and working points cannot be changed without altering the structure of the machine; and therefore we must find the ratio between the power and resistance, which will enable us to obtain a maximum effect. The method of determining this will be shown in the following proposition.

Prop. II.

To determine the ratio between the power and the resistance of a machine when its performance is a maximum.

Since the structure of the machine is given, the values of x, y are known, and therefore we have to determine the relative values of P and R when the effect of the machine is a maximum. This would be easily done by making R variable in the formula which expresses the performance of the machine, and making its fluxion equal to 0, if none of the other quantities varied along with R. It often happens, however, that while R varies, the mass b suffers a considerable change, though in other cases the change induced upon b is too unimportant to merit notice. This proposition, therefore, admits of two cases; 1. when the change upon b is so small that it may be safely omitted in the investigation; and, 2. when the change upon b is sufficiently great to require attention.

Case 1. When R is the only quantity which is variable, the fluxion of the formula

$$\frac{Pxy\dot{R}-R^2y^2-\varphi\dot{R}y^2}{ax^2+by^2+my^2},$$

which represents the work performed, is equal to the fluxion of the numerator, because the denominator is constant, that is, $Pxy\dot{R}-2R\dot{R}y^2-\varphi\dot{R}y^2=0$; and, dividing by $\dot{R}$, $Pxy-2Ry^2-\varphi y^2=0$; hence $2Ry^2=Pxy-\varphi y^2$, and $R=\frac{Pxy-\varphi y^2}{2y^2}$, which, divided by y, gives $R=\frac{Px-\varphi y}{2y}$.

Now, according to the experiments of Coulomb, the friction is, in general, proportional to the resisting pressure, or a certain part of that pressure, for example, $\frac{1}{13}R$; and calling $Z=\frac{1}{13}$, and omitting φy, we have for the resistance $R+\frac{1}{13}R$, or $\frac{16}{13}R=\frac{Px-\varphi}{2y}$, or $R=\left(\frac{Px}{2y}\right)\div\frac{16}{13}$; and making $P=1$, and $x=1$, we have $R=\left(\frac{1}{2y}\right)\div\frac{16}{13}$, so that, abstracting from the quotient $\frac{16}{13}$, which, being little greater than 1, will not alter the result, the resistance should be one half of the force which would keep the impelling power in equilibrio.

Case 2. When b varies at the same time with R, it will in most cases vary in the same proportions, and therefore may be represented by any multiple of R, as dR, where d may be either an integer or a fraction. In order to simplify the investigation, we may consider the fraction φ as a resistance diminishing the impelling power, instead of regarding it as a resistance to be added to the other resisting forces. Thus the impelling power P will become $P-\varphi$. In the same way we may consider the momentum of the machine's inertia applied to the impelled point, that is, instead of my^2, it may be made mx^2. Now, making $P-\varphi$, or the impelling power $=1$, and making $x=1$, we shall have by these substitutions in the formula which expresses the effect of the machine, $\frac{Ry-R^2y^2}{a+m+dRy^2}$, or, for the sake of simplicity, making $a+m=q$, we have for the performance of the machine $\frac{Ry-R^2y^2}{q+dry^2}$; then, since R is the variable quantity, we shall find, after making the fluxion of this formula $=0$, that the performance is a maximum when $R=\frac{\overline{q^2+qdy}|\frac{1}{2}-q}{dy^2}$.

When $b=R$, then $d-1$, and we shall have

$$R=\frac{\overline{q^2+qy}|\frac{1}{2}-q}{y}.$$

When $a=P$ and $P=1$, and when m, the inertia of the machine, $=0$, we shall have $a+m=1=q$, and then the formula becomes

$$R=\frac{\overline{y+1}|\frac{1}{2}-1}{y^2}.$$

When $y=x$, then $y=1$, and

$$R=\frac{\overline{1+1}|\frac{1}{2}-1}{1}=0{\cdot}4142.$$

Scholium.

Those who wish to prosecute this interesting subject may consult the different papers of Euler in the *Comment. Petropol.* vol. x. p. 80, 1743, and in the *Comment. Nov. Petropol.* vol. iii. and viii. This subject has been treated with great ability by Dr Robison, though he has omitted the various steps in the investigation which conduct to the leading formulæ. The subject has been also ably discussed by Sir John Leslie, in a paper published in the first edition of the appendix to Ferguson's Lectures, vol. ii. p. 353; and as the results of his investigations may be of great use in practice, we shall here present the reader with a short abstract of them.

If the resistance is equal to the power, or double, triple, or quadruple, &c. a maximum effect will be produced when the velocity of the power, or its distance from the centre of motion, is $1+\sqrt{2}$, $2+\sqrt{6}$, $3+\sqrt{12}$, $4-\sqrt{20}$, $5+\sqrt{30}$, $6+\sqrt{42}$, that of the weight being 1, &c. If the resistance is very great compared with the power, the velocity should at least be double of that which would procure an equilibrium, in order that the machine may produce a maximum effect.

If the velocity of the power, or its distance from the centre of motion, be equal to, double, triple, quadruple, &c. &c. of the velocity of the weight or resistance, a maximum effect will be produced when the power P is equal to $R\times\overline{1+\sqrt{2}}$, $R\times\sqrt{\frac{1}{2}+\sqrt{\frac{3}{8}}}$, $R\times\frac{1}{3}+\sqrt{\frac{4}{27}}$, $R\times\frac{1}{4}+\sqrt{\frac{5}{64}}$, $R\times\frac{1}{5}+\sqrt{\frac{6}{125}}$, &c. where R is the resistance or weight to be raised. If the velocity of the power be very large, a maximum effect will be produced when the power P is at least double of that which would procure an equilibrium. It appears also, from Sir John Leslie's paper, that in whatever way the maximum be procured, the force which impels the weight can never amount to one fourth part of the direct action of the power; and that, in ma-

On the Equilibrium of Arches.

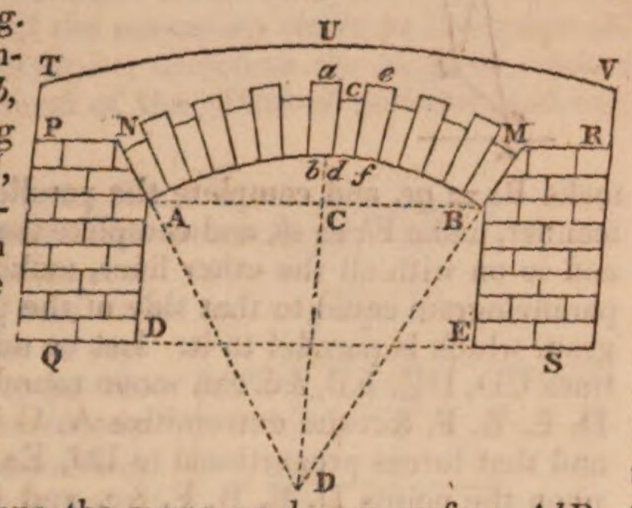
chines where the velocity of the power is great, we may disregard the momenta of the connecting parts, and consider the force which ought to be employed as double of what is barely able to maintain the equilibrium.

CHAP. VIII.—ON THE EQUILIBRIUM OF ARCHES, PIERS, AND ABUTMENTS.

Equilibrium of arches.

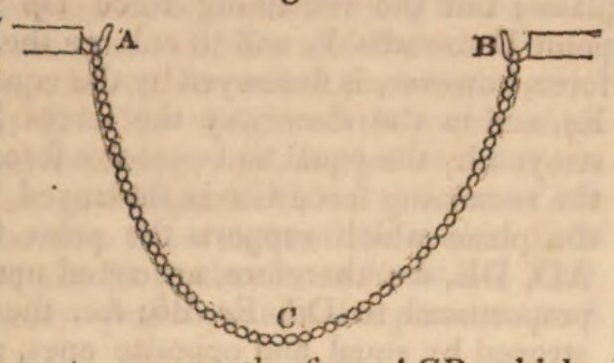
DEF. 1. An arch is represented in fig. 92 by the assemblage of stones *ab*, *cd*, *ef*, &c. forming the mass ABMN, whose inferior surface is the portion of a curve. The parts A, B are called the *spring of the arch*, the line AB the *span of the arch*, *Cb* its *altitude*, *b* its crown, *ab* the *keystone*, the curve or lower surface *AbB* the *intrados*, and the roadway TUV the *extrados*; PQ, RS, the *piers* when they stand between two arches, and the *abutments* when they are at the extremities of the bridge.

Fig. 92.



DEF. 2. A catenarian curve is the curve formed by any line or cord perfectly flexible, and suspended by its extremities. Thus if the chain ACB be suspended by its extremities A, B, it will, by the action of gravity upon all its parts, assume the form ACB, which is called the catenary, or catenarian curve.

Fig. 93.



There are three modes of determining the construction of arches; the first of which is to consider the arch as an inverted catenary; the second is to establish an equilibrium between the vertical pressures of all the materials between the intrados and extrados; and the third is to regard the different arch-stones as portions of wedges without friction, which endeavour by their own weight to force their way through the arch. The first of these methods was given by the ingenious Dr Hook, and is contained in the following proposition.

PROP. I.

To determine the form of an arch by considering it as an inverted catenary, when its span, its altitude, and the form of the roadway or extrados, are given.

Let *a*, *b*, *c*, *d*, &c. be a number of spheres or beads connected by a string, and suspended by their extremities A, B; they will form a catenarian curve *AabcB*, and be in equilibrio by the action of gravity. Each sphere is acted upon by two forces: at its lower point by the weight of the spheres immediately below it, and at its upper point by the weight of the same spheres added to that of the sphere itself; that is, any sphere *c* is in equilibrio from the result of two forces, one of which is produced by the weights of *c*, *d*, *e* acting at the lower point of *b*, while the other force arises from the weight of *bcde* acting at its upper point. The equilibrium of this chain of spheres is evidently of the stable kind, as it will immediately recover its position when the equilibrium is disturbed. Let us now suppose this arch inverted, so as to stand in a vertical plane, as in fig. 95. It will still preserve its equilibrium. For the relative positions of the lines which mark the directions remain unchanged by inverting the curve, the force of gravity continues the same, and therefore the result of these forces will be the same, and the arch will be in equilibrio. The equilibrium, however, which the arch now possesses is of the tottering kind, so that the least disturbing force will destroy it, and it will consequently be unable to support any other weight but its own.

Fig. 94.

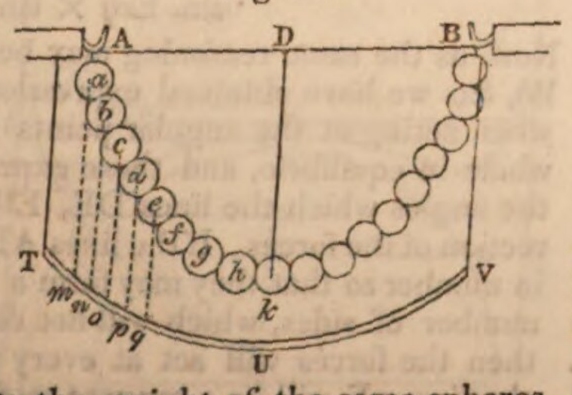


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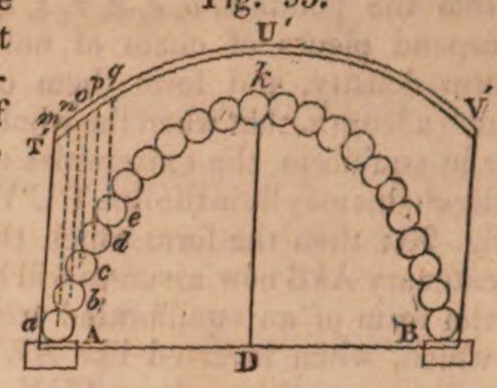
Fig. 95.



Let us now suppose that it is required to form an equilibrated arch, whose span is AB, whose altitude is D*k*, and which will support the materials of a roadway, whose form TUV is given. It is obvious, that if the spheres *a*, *b*, *c*, *d*, &c. increase in density from *k* towards *a*, the catenarian curve will grow less concave at its vertex *e*, and more concave toward its extremities A, B. Let us then suppose that the densities of the spheres *a*, *b*, *c*, *d*, *e*, &c. are respectively as *am*, *bn*, *co*, *dp*, *eq*, &c. the vertical distances of their respective centres from the roadway TUV, the arch will have a form different from that which it would have assumed if the spheres were of equal density, and will be in equilibrio when inverted as in fig. 95. Now, in place of the spheres *a*, *b*, *c*, *d*, *e*, &c. of different densities, let us substitute spheres of the same density, and having the same position as those of different densities; let us then load the sphere *a* with a weight which, when combined with the weight of *a*, will be equal to the weight of the corresponding sphere *a*, that had a greater density; and let us load the other spheres *b*, *c*, *d*, &c. with weights proportional to *bn*, *co*, *dp*, &c. Then it is obvious that the pressure of each sphere when thus loaded upon that which is contiguous to it, is precisely equal to the pressure of the spheres of different densities upon each other, because the density of these spheres varied as their distances from the roadway. But the arch composed of spheres of different densities was in equilibrio when inverted, therefore, since the loaded spheres of the same density have the same position and exert the same pressures, the arch composed of these spheres, and supporting TUVB*k*A, composed of homogeneous materials, will be in equilibrio. *Hence a roadway of a given form, and composed of homogeneous materials, will be supported by an arch whose form is that of a catenary, each of whose points varies in density as their distance from the surface of the roadway*; or, which is the same thing, *a roadway of a given form, and composed of homogeneous materials, will be supported by an arch whose form is that of a catenary, each of whose points is acted upon by forces proportional to the distances of these points from the surface of the roadway.*

Hence we have the following practical method of ascertaining the form of an equilibrated arch, whose span is AB, and altitude D*k*, and which is to support a roadway of the form T'U'V'. Let a chain *AabckB*, of uniform density, be suspended from the points A, B, so that it forms a catenary whose altitude is D*k*, the required height of

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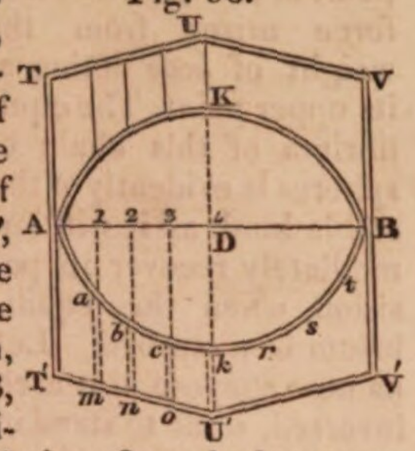
the arch. Divide AB into any number of equal parts, suppose eight, and let the vertical lines 1*m*, 2*n*, 3*o*, drawn from these points, intersect the catenary in the points *a*, *b*, *c*. From the points *a*, *b*, *c*, *k*, *r*, *s*, *t*, suspend pieces of chain of uniform density, and form them of such a length, that when the whole is in equilibrio, the extremities of the chains may lie in the line T′U′V′, fig. 95; then the form which the catenary A*k*B now assumes will be the form of an equilibrated arch, which, when inverted like AKB, will support the roadway TUV, similar to T′U′V′, fig. 95. This is obvious from the last paragraph, for the pieces of chain *am*, *bn*, *co*, *k*U, &c. are forces acting upon the points *a*, *b*, *c*, *k* of the catenary, and are proportional to *am*, *bn*, *co*, &c. the distances of the points *a*, *b*, *c*, *k*, &c. from the roadway.

Fig. 96.



An arch of this construction will evidently answer for a bridge, in which the weight of the materials between the roadway and the arch-stones is to the weight of the arch-stones as the weight of all the pieces of chain suspended from *a*, *b*, *c*, &c. is to the weight of the chain A*k*B. As the ratio, however, of the weight of the arch-stones to the weight of the superincumbent materials is not known, we may assume a convenient thickness for the arch-stones; and if from this assumed thickness their weight be computed, and be found to have the required ratio to the weight of the incumbent mass, the curve already found will be a proper form for the arch. But if the ratio is different from that of the weight of the whole chain to the weight of the suspended chains, it may be easily computed how much must be added to or subtracted from the pieces of chain, in order to make the ratios equal. The new curve which the catenary then assumes, in consequence of the change upon the length of the suspended chains, will be the form of an equilibrated arch, the weight of whose arch-stones is equal to that which we assumed.

Scholium.

In most cases the catenarian curve thus determined will approach very near to a circular arc equal to 120 degrees, which springs from the piers so as to form an angle of 60 degrees with the horizon. The form of the arch, however, as determined in the preceding proposition, is suited only to those cases in which the superincumbent materials exert a vertical pressure. A quantity of loose earth and gravel exerts a pressure in almost every direction, and therefore tends to destroy the equilibrium of a catenarian arch. This tendency, however, may be removed by giving the arch a greater curvature towards the piers. This will make it approach to the form of an ellipsis, and make it spring more vertically from the piers or abutments.

We shall now proceed to deduce the form of an arch and its roadway, by establishing an equilibrium among the weights of all the materials between the arch and the roadway. This method was given by Emerson in his *Fluxions*, published in 1742; and afterwards by Dr Hutton in his excellent work *On Bridges*.

Prop. II.

To determine the form of the roadway or extrados, when the form of the arch or intrados is given.

Let the lines AD, DE, EB, BF, FG, GH lie in the same plane, and let them be placed perpendicular to the horizon. From the points D, E, B, &c. draw the vertical lines D*d*, E*e*, B*b*, &c. and taking D*p* of any length, make E*r* equal to D*p*, &c. and complete the parallelograms *pc*, *rq*. Again,

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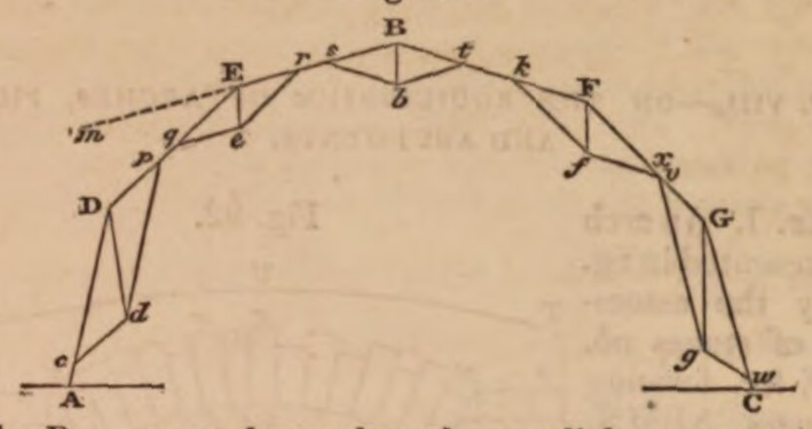
Fig. 97.



make B*s* = *qe*, and complete the parallelogram *ts*; in like manner, make F*k* = *sb*, and complete the parallelogram F*f*; and so on with all the other lines, making the side of each parallelogram equal to that side of the preceding parallelogram which is parallel to it. Let us now suppose that the lines CD, DE, EB, &c. can move round the angular points D, E, B, F, &c. the extremities A, C being immoveable; and that forces proportional to D*d*, E*e*, B*b*, &c. are exerted upon the points D, E, B, F, &c. and in the direction D*d*, E*e*, &c. Now, by the resolution of forces, the force D*d* may be resolved into the forces D*c*, D*p*, the force E*e* into the forces E*q*, E*r*, and the force B*b* into the forces B*s*, B*t*, and so on with the rest. The force D*c* produces no other effect than to press the point A on the plane on which it rests, and is therefore destroyed by the resistance of that plane; but the remaining force D*p* tends to bring the point D towards E, and to enlarge the angle ADE; this force, however, is destroyed by the equal and opposite force E*q*, and in the same way the forces E*r*, B*t*, F*x* are destroyed by the equal and opposite forces B*s*, F*k*, G*v*, while the remaining force G*w* is destroyed by the resistance of the plane which supports the point C. When the lines AD, DE, &c. therefore, are acted upon by vertical forces proportional to D*d*, E*e*, B*b*, &c. these forces are all destroyed by equal and opposite ones, and the lines will remain in equilibrio.

Now the force D*c* : D*p* or E*q* = sin. *cd*D or *d*D*p* : sin. AD*d*, that is, by taking the reciprocals,

$$\mathrm{D}c : \mathrm{E}q = \frac{1}{\sin. \mathrm{AD}d} : \frac{1}{\sin. d\mathrm{D}p};$$

and, for the same reason,

$$\mathrm{E}q : \mathrm{B}s = \frac{1}{\sin. \mathrm{E}eq} : \frac{1}{\sin. b\mathrm{B}s}.$$

Hence

$$\mathrm{E}q \doteqdot \frac{1}{\sin. \mathrm{E}eq}.$$

Now, since E*q* : E*e* = sin. E*eq* : sin. E*qe*, we have E*e* = $\frac{\mathrm{E}q \times \sin. \mathrm{E}qe}{\sin. \mathrm{E}eq}$; that is, since DE*m* = E*qe*, and *e*EB = E*eq*;

$$\mathrm{E}e = \frac{\mathrm{E}q \times \sin. \mathrm{DE}m}{\sin. e\mathrm{EB}}.$$

But $\mathrm{E}q \doteqdot \frac{1}{\sin. \mathrm{E}eq}$, therefore, by substitution, we obtain

$$\mathrm{E}e \doteqdot \frac{\sin. \mathrm{DE}m}{\sin. \mathrm{E}eq \times \sin. e\mathrm{EB}}.$$

Now, as the same reasoning may be employed to find D*d*, B*b*, &c. we have obtained expressions of the forces which, when acting at the angular points D, E, B, &c. keep the whole in equilibrio, and these expressions are in terms of the angles which the lines DE, EB, &c. form with the direction of the forces. If the lines AD, DE, &c. be increased in number so that they may form a polygon with an infinite number of sides, which will not differ from a curve line, then the forces will act at every point of the curve, and the line *m*E will be a tangent to the curve at the point E,

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and DE*m* will be the angle of contact. The line E*q* being now infinitely small, will coincide with E*m*, and therefore the angles *e*E*q* and *e*EB or E*eq* will be equal to the angle *e*E*m*, and consequently their sines will be equal. Therefore, by making these substitutions in the last formula, we have an expression of the force at every point of the curve, thus,

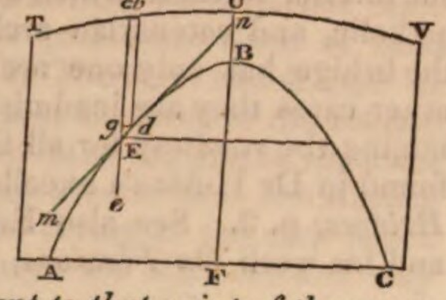
$$Ee \doteqdot \frac{\text{sin. DE}m}{\text{sin. }e\text{E}m \times \text{sin. }e\text{E}m} \doteqdot \frac{\text{sin. DE}m}{\text{sin. }e\text{E}m|^2}.$$

But the angle of contact DE*m* varies with the curvature at the point E, and the curvature varies as the reciprocal of the radius of curvature, therefore the angle of contact varies as the reciprocal of the radius of curvature; hence, by substitution,

$$Ee \doteqdot \frac{1}{\text{radius of curvature} \times \overline{\text{sin. }e\text{E}m^2}}.$$

In order to get rid of the confusion in fig. 97, where the arch is a polygon, let us suppose ABC, fig. 98, to be the curve, *mn* a tangent to any point E, and Ee a vertical line; *then the pressure at any point of the arch is reciprocally as the radius of curvature at that point, and the square of the sine of the angle which the tangent to that point of the curve forms with a vertical line.*

Fig. 98.



Corollary. Let us now suppose that the arch ABC supports a mass of homogeneous materials lying between the roadway TUV and the arch AEBC; and the whole being supposed in equilibrio, let us determine the weight which presses on the point E. The weight of the superincumbent column E*cbd* varies as Ec × *gd*, but *gd* = E*d* × sin. *d*E*g*, E*d* being radius, and *d*E*g* = E*n*B, on account of the parallels E*c*, UB, therefore the weight of the column E*cbd* varies as Ec × E*d* × sin. E*n*B, that is, as Ec × sin. E*n*B, because E*d* is a constant quantity; but the pressure at E was proved to vary as $\frac{1}{\text{radius curvature} \times \overline{\text{sin. }e\text{E}m^2}}$, therefore the weight of the column E*cbd* or Ec × sin. E*n*B varies also as this quantity, that is,

$$Ec \times \text{sin. E}n\text{B} \doteqdot \frac{1}{\text{radius curvature} \times \text{sin. }e\text{E}m^2}.$$

But as the angle E*n*B is equal to the angle *e*E*m*, we shall have, by substitution and division,

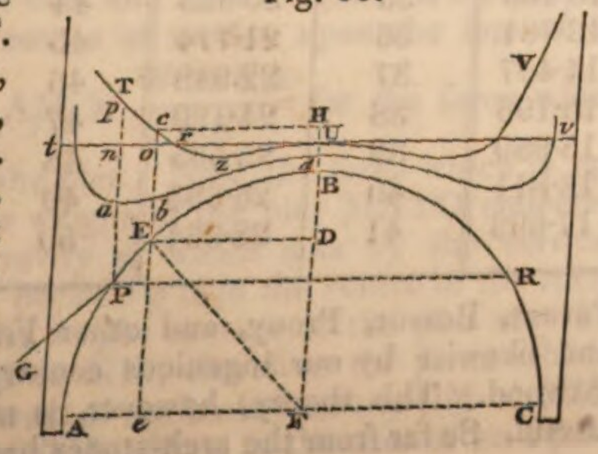
$$Ec \doteqdot \frac{1}{\text{radius curvature} \times \overline{\text{sin. }e\text{E}m^3}}, \text{ that is,}$$

When an arch supports a roadway, the pressure exerted upon any point of it is reciprocally as the radius of curvature, and the cube of the sine of the angle which the tangent to that point forms with a vertical line.

Having thus obtained an expression for Ec, we shall proceed to show the application of the formula to the case when the arch is a portion of a circle.

Let EB be the arch of a circle whose centre is F. Let the radius = R, BD = versed sine, BE = *x*, DF = cos. BE = *b*, BU = *m*. Draw the tangent GE, and through E the vertical line *ce*, which will be parallel to BE. Then, since GEF is a right angle, and *e*EF = EFB, the angle GE*e* is the complement of EFB, therefore sin. GE*e* = cos. EFB = FD. But, in the present case, the radius of curvature is the radius of the arch, or R, therefore Ec $\doteqdot \frac{1}{\text{R} \times \text{sin. GE}e}$, or, by substitution, Ec $\doteqdot \frac{1}{\text{R}b^3}$, that is, since R is constant, Ec $\doteqdot \frac{1}{b^3}$. But when the point E coincides with B, the cosine *b* becomes equal to radius; therefore, in that case, Ec $\doteqdot \frac{1}{\text{R}^3}$, and Ec becomes BU = *m*, hence $\frac{1}{\text{R}^3} : \frac{1}{b^3} = m : Ec$ and $Ec = \frac{mb^3}{b^3}$. Now, by the notation R : *b* = BF : DF; therefore $\text{R}^3 : b^3 = \overline{\text{BF}^3} : \text{DF}^3$, hence $\frac{\text{R}^3}{b^3} = \frac{\overline{\text{BF}^3}}{\text{DF}^3}$, and, multiplying each side by *m*, we have $\frac{m\text{R}^3}{b^3} = \frac{m\overline{\text{BF}^3}}{\text{DF}^3}$; but $\frac{m\text{R}^3}{b^3} = Ec$, therefore the vertical distance of the surface of the roadway from the point F, or $Ec = \frac{m\overline{\text{BF}^3}}{\text{DF}^3} = \frac{\text{BU} \times \overline{\text{BF}^3}}{\text{DF}^3}$. When the point E coincides with B, BF = DF, and E*e* = BU. When E coincides with A, the cosine DF vanishes, and therefore Ec, or the distance of the point A from the extrados or roadway, is infinite. The curve V*U*c*T*, therefore, will run up to an infinite height, approaching continually to a vertical line drawn from A, which will be its asymptote. Such a form of the extrados, however, is inadmissible in practice; and therefore a semicircular arch is not an arch of equilibration. When the arch is less than a semicircle, as PBR, the curve terminates in the point *p*; and as it does not rise very much above a horizontal line passing through U when the arch is small, we might produce a perfect equilibrium by making the horizontal, as *tUv*, and making the density of the superincumbent columns P*n*, E*o*, which press upon the points P, E respectively, in the ratio of P*p*, Ec, the distances of these points from the curvilineal roadway.

Fig. 99.



The inconvenience, however, arising from the inflexion of the extrados, may be considerably removed by throwing the point of contrary flexure to a greater distance, which may be done by diminishing BU, the thickness of the incumbent mass above the keystone. Thus, if BU is diminished to B*d*, and if points *a*, *b* are taken in the lines P*p*, Ec, so that P*a* : P*p* = E*b* : Ec = B*d* : BU, and so on with all the points in the arch, and if a new roadway *vdbat* be drawn through these points, the equilibrium of the arch will still continue, for the various pressures which it sustained, though they are diminished, preserve the same proportion.

Let us suppose it necessary to have the extrados a horizontal line, and let it be required to find BU = *m* when there is an equilibrium. In this case the point H coincides with U; or rather, when the curve U*c*T cuts the horizontal line *tUv*, the point H coincides with U. By substituting BF — BD instead of DF in the value Ec, formerly determined, and by putting BD = *y*, we have $Ec = \frac{m\text{R}^3}{\overline{\text{R}-y|^3}}$. But when H coincides with U, *c* coincides with *o*, and therefore Eo = Ec = BD + BU = *y* + *m*, consequently, $\frac{m\text{R}^3}{\overline{\text{R}-y|^3}} = y + m$; and, multiplying by $\overline{\text{R}-y|^3}$, we have $m\text{R}^3 = y \times \overline{\text{R}-y|^3} + m \times \overline{\text{R}-y|^3}$, or $m\text{R}^3 + m$

On the Equilibrium of Arches.

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$\times \overline{R-y}|^3 = y \times \overline{R-y}|^3$, and, dividing by the co-efficients of m, we have

$$m = \frac{y \times \overline{R-y}|^3}{R^3 - \overline{R-y}^3}; \text{ that is,}$$

The thickness of the roadway above the keystone, when the extrados is a straight line, is equal to the quotient arising from multiplying the versed sine of half the arch by the cube of its cosine, and dividing this product by the difference between the cube of the radius and the cube of the cosine; or, to change the expressions, *the thickness of the roadway above the keystone, when the roadway is a straight line, is equal to the quotient arising from multiplying the height of the arch by the cube of the difference between the radius of the arch and its height, and dividing this product by the difference between the cube of the radius and the cube of the difference between the radius and the height of the arch.*

When the arch is a semicircle, $R - y$ vanishes, and m becomes equal 0, so that the semicircular arch is evidently inadmissible. But when the arch is less than a semicircle, the value of m will be finite. Thus, if the arches are respectively

Arch.
60°, we have $m = \frac{1}{4}$ of the span,
90°, we have $m = \frac{1}{2}$ of the span, or
110°, we have $m = \frac{1}{17}$ of the span nearly.

The two first arches of 60° and 90° manifestly give too great a thickness to the part BU or m. In the third arch of 110°, the thickness of BD is nearly what is given to it by good architects, and is therefore the best in practice; for if the arch were made greater than 110°, the thickness of BU or m would be too small. It is obvious, however, that an arch of 110° is not an arch of *perfect* equilibration, for this can be the case only when the roadway has the form U*zr*, fig. 95. When the roadway, therefore, is horizontal, as U*r*, there is an unbalanced pressure on both sides of the keystone, produced by the weight of the materials in the mixtilinear space *rz*U. It is indeed very small, and might be counteracted by making the materials below Z lighter than those below U; but the unbalanced pressure is so trifling that it may be safely neglected. We may therefore conclude, *that when the arch is to be circular with a horizontal roadway, an arch of* 110 *degrees approaches nearest to an arch of equilibration.*

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When the arch is elliptical, it will be found, as in the circle, that $m = \frac{y \times \overline{R-y}|^3}{R^3 - \overline{R-y}^3}$. An elliptical arch, however, has the advantage of a circular one, when the transverse axis is horizontal; for, as it is much flatter, the point of contrary flexure in the extrados is thrown at a greater distance, and therefore it will, with less inconvenience, admit of a horizontal roadway. Elliptical arches have also the advantage of being more elegant, and likewise require less labour and materials.

Elliptical arches superior to circular arches when their transverse axis is horizontal.

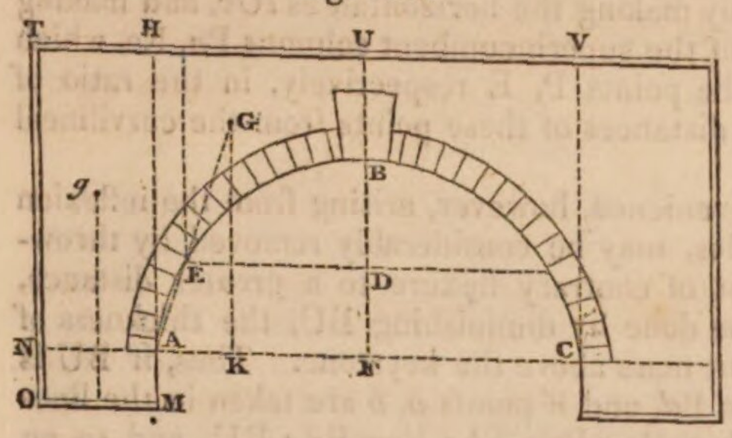
The cycloidal arch is likewise superior to a circular one, but inferior to those which are elliptical. Parabolic, hyperbolic, and catenarian arches may be employed when the bridge has only one arch, and is to rise high; but in other cases they are inadmissible. The method of determining the roadway for all these forms of arches will be found in Dr Hutton's excellent work *On the Principles of Bridges*, p. 3. See also Emerson's *Miscellanies*, p. 156; and his work *On Fluxions*, published in 1742.

On the mechanical curve of equilibration.

When the form of the roadway is given, the shape of the intrados for an arch of equilibration may be determined. As the investigation is very difficult, unless when the roadway is a horizontal line, we shall merely give the formula, which will enable any person to construct the curve. In all other curves the equilibrium of the arch is imperfect; but the curve described by the following formula is an arch of perfect equilibration, and has been called *the mechanical curve of equilibration:*

$$ED = AF \times \frac{\text{hyperbol. log. } \frac{BU + BD + \sqrt{2BU \times BD + BD^2}}{BU}}{\text{hyperbol. log. } \frac{BU + BF + \sqrt{2BU \times BF + BF^2}}{BU}}$$

Fig. 100.



From this formula, which corresponds with fig. 100, Dr Hutton has computed the following table, containing the values of *c*U and *c*E, for an arch whose span AC is 100, whose height BF is 40, and whose thickness at the crown or BU is 6. The table will answer for any other arch whose span and thickness are as the numbers 100, 40, 6; only the values of *c*U and *c*E must be increased or diminished in the same ratio as these numbers.

Table for constructing the Curve of Equilibration, when the Span, Height, and Thickness at the Crown, are as the Numbers 100, 40, *and* 6.

Value of *c*U.	Value of *c*E.	Value of *c*U.	Value of *c*E.	Value of *c*U.	Value of *c*E.	Value of *c*U.	Value of *c*E.	Value of *c*U.	Value of *c*E.
0	6·000	15	8·120	24	11·911	33	18·627	42	29·919
2	6·035	16	8·430	25	12·489	34	19·617	43	31·563
4	6·144	17	8·766	26	13·106	35	20·665	44	33·299
6	6·324	18	9·168	27	13·761	36	21·774	45	35·135
8	6·580	19	9·517	28	14·457	37	22·948	46	37·075
10	6·914	20	9·934	29	15·196	38	24·190	47	39·126
12	7·330	21	10·381	30	15·980	39	25·505	48	41·293
13	7·571	22	10·858	31	16·811	40	26·894	49	43·581
14	7·834	23	11·368	32	17·693	41	28·364	50	46·000

The construction of arches has also been deduced from considering the arch-stones as frustums of polished wedges without friction, which endeavour to force their way through the arch. This principle has been adopted by Belidor, Parent, Bossut, Prony, and other French philosophers, and likewise by our ingenious countryman the late Mr Atwood. This theory, however, is more plausible than useful. So far from the arch-stones having liberty to slide

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between those which are contiguous to them, without friction, they are bound together by the strongest cement, and sometimes connected by iron pins or wedges. The theory likewise requires that the weight of the arch must regularly increase as the portion of the vertical tangent cut off by lines drawn from a given point in a direction parallel to that of the joints, and therefore either the density or the magnitude of the arch-stones must be very great at the spring of the arch, where the portion of the vertical tangent is a maximum. Those who wish to be acquainted with the mode of investigation by which the equilibrium of arches is established in this theory, may consult Prony's *Architecture Hydraulique*, tom. i. p. 152.

On the Construction of Piers and Abutments.

Construction of piers and abutments.

In the construction of piers and abutments, there are two circumstances which claim our attention. 1. The strength that must be given to them in order to resist the lateral thrust which they sustain from the adjacent semi-arches, and which tend either to overset them or make them slide upon their base. 2. The form which must be given to their extremities, so that the force of the current may be a minimum. The adhesion of the pier to the place on which it rests is always much greater than one third of the pressure; and as the lateral thrust of the arch which this adhesion resists is oblique to the horizon, and may be resolved into two forces, one of which is horizontal, and the other vertical, we have the vertical portion of the lateral thrust, the weight of the pier, and the friction on its base, combined in resisting the horizontal portion of the lateral thrust which tends to make the pier slide upon its base, so that there is no danger of the pier yielding to such a pressure. We do not here consider, that the lateral thrust which tends to give a horizontal motion to the pier is completely counteracted by the lateral thrust of the opposite semiarch, because it is necessary that the pier should have sufficient stability to resist the lateral thrust of one semiarch, in case of the failure of the opposite one. Let us therefore consider the strength of the pier which will prevent it from being overset.

For this purpose, let ABC, fig. 100, be an arch, MHTO the pier, and BUHA the loaded semiarch, whose pressure tends to overturn the pier. Let G be the centre of gravity of the mass BUHA. Join GA, and from G draw GK perpendicular to AC, fig. 100. Then, since the whole pressure of the arch is exerted at its spring A, and since this pressure is the same as if the whole weight of the arch were collected into the point G, GA will be the direction in which the weight of the arch and the superincumbent mass acts upon the point A. Now, by Dynamics, the force GA may be resolved into the two forces GK, KA, one of which, KA, endeavours to give the pier a motion of rotation about the point O, while the other, GK, denotes the weight of the loaded arch in the direction GK. Putting W, therefore, for the weight or area of the superincumbent mass, we have $GK : KA = W : \frac{W \times KA}{GK}$, the pressure upon A. Now, as this force tends to turn the pier round O by means of the lever OA, and as ON = AM is the perpendicular from the centre of motion upon the line of direction, we have $AM \times \frac{W \times KA}{GK}$ for the force which tends to overturn the pier. Now, the force which is opposed to this is the weight of the pier MHTO collected in its centre of gravity *g*, which acts by the vertical lever $Om = \frac{1}{2}OM$, because *g* is in the centre of the rectangle TM. But the weight or area of the pier may be represented by OM × MH; therefore the force which resists the lateral thrust of the loaded arch is $OM \times MH \times \frac{1}{2}OM$, or $\frac{1}{2}MH \times OM$. Now, in the case of an equilibrium between these opposing forces, we have $AM \times \frac{W \times KA}{GK} = \frac{1}{2}MH \times OM^2$, which, by reduction, becomes $OM = \sqrt{\frac{2AM \times W \times KA}{MH \times GK}}$. This formula gives us the breadth of the pier which is capable of balancing the lateral thrust, and therefore OM must be taken a little greater than the preceding value. In practice, OM is generally between one fifth and one seventh of AC, the span of the arch. The method of finding the centre of gravity G of the loaded arch, whether the arch is in perfect equilibrium or not, may be seen in Dr Hutton's work already quoted, p. 49. A very simple method of doing this is to form the part BUHA of a piece of card, and to find its centre of gravity G by the rules already given. This indeed supposes all the materials to be homogeneous; but if they are of various kinds, we can load the arch made of card in a similar manner, and determine its centre of gravity as before.

On the Force of Torsion.

The limits of this article will not permit us to apply the method of fluxions to the determination of the form which should be given to the ends of the pier, in order that the impulse of the current may be the least possible. The theory of the resistance of fluids, indeed, differs so widely from experiment, that such an investigation would, in this place, be of little practical utility. It may be sufficient merely to remark, that the pier should have an angular form, and that the impulse of the current will be diminished as the angle is more acute. When the ends are semicircular, the impulse of the stream is reduced to one half; and though a triangular termination of the piers reduces the impulse still more, yet semicircular ends are more pleasing to the eye, and are particularly advantageous when small vessels have occasion to pass the arch. When such vessels happen to impinge against the piers, the semicircular ends are more able to bear the shock, and do less injury to the vessel, while the additional quantity of masonry will give greater stability to the pier.

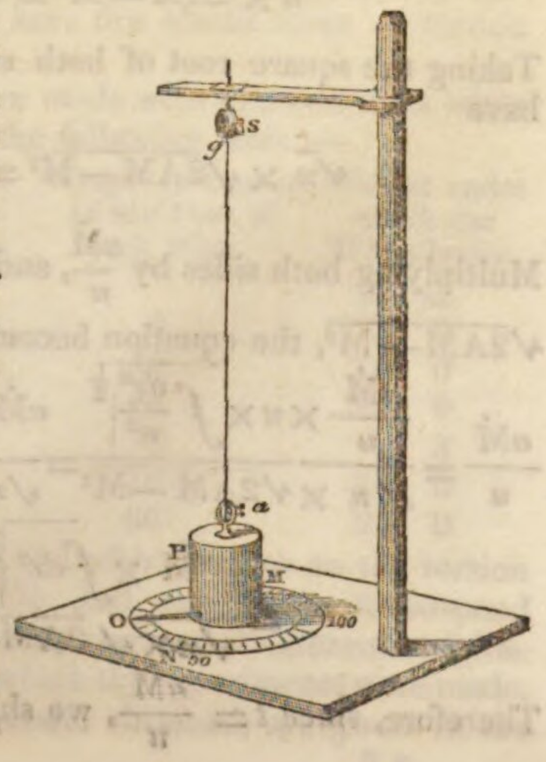
For fuller details on the subject of this chapter, and on that of domes, cupolas, and octagonal pyramids, see the article Arch in this work, vol. iii. p. 378.

CHAP. IX.—ON THE FORCE OF TORSION.

On the force of torsion.

Definition. Let *ga* be a metallic wire firmly fixed in the pincers *g*, by means of the screw *s*; let the cylindrical weight P, furnished with an index *o*, be suspended at the lower extremity of the wire; and let the axis of the cylinder, or the wire *ga* produced, terminate in the centre of the divided circle MNO. Then, if the cylinder P is made to move round its axis so that the index *o* may describe the arch ON, the wire *ga* will be twisted. If the cylinder be now left to itself, the wire will, in consequence of its elasticity, endeavour to recover its form; the index *o* will therefore

Fig. 101.



On the Force of Torsion.

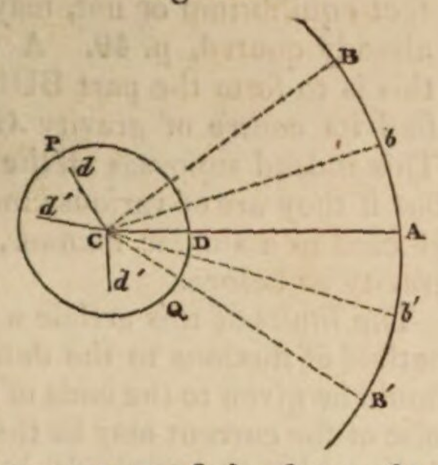
move backwards from N, and oscillate round the axis of the cylinder. The force which produces these oscillations is called the *force of torsion*, and the angle measured by the arch ON is called the *angle of torsion*.

Prop. I.

To deduce formulæ for the oscillatory motion of the cylinder, on the supposition that the re-action of the force of torsion is proportional to the angle of torsion, or nearly proportional to it.

Let PQ be a section of the cylinder P in fig. 101, and let all the elements of the cylinder be projected upon this circular section in d, d', d''. Let ACB, the primitive angle of torsion, be called A, and let this angle, after the time t, become ACb, so that it has been diminished by the angle BCb = M; then ACb = A − M = the angle of torsion after the time t.

Fig. 102.



Since the force of torsion is supposed to be proportional to the angle of torsion, the momentum of the force of torsion must be some multiple of that angle, or $n \times \overline{A - M}$, n being a constant co-efficient, whose value depends on the nature, length, and thickness of the metallic wire. If, therefore, we call v the velocity of any point d at the end of the time t, when the angle of torsion becomes ACb, and r = Cd the distance of the point d from the axis of rotation C, we shall have, by the principles of dynamics,

$$n \times \overline{A-M} \times \dot{t} = \int dr\dot{v}.$$

But if CD, the radius of the cylinder, be equal a, and if u be the velocity of the point D after the time t, we have evidently $v : u = r : a$, and $v = \frac{ru}{a}$. Now, by substituting the fluxion of this value of v in the place of $\dot{v}$ in the preceding formula, we have

$$n \times \overline{A-M} \times \dot{t} = \dot{u} \int \frac{dr^2}{a};$$

and since $\dot{t} = \frac{a\dot{M}}{u}$, we have, by substitution,

$$n \times \overline{A-M} \times \frac{a\dot{M}}{u} = \dot{u} \int \frac{dr^2}{a},$$

whose fluent is

$$n \times \overline{2AM - M^2} = u^2 \int \frac{dr^2}{a^2}.$$

Taking the square root of both sides of the equation, we have

$$\sqrt{n} \times \sqrt{2AM - M^2} = u \times \overline{\int \frac{dr^2}{a^2}\Big|}^{\frac{1}{2}}.$$

Multiplying both sides by $\frac{a\dot{M}}{u}$, and dividing by $\sqrt{n} \times \sqrt{2AM - M^2}$, the equation becomes

$$\frac{a\dot{M}}{u} = \frac{\frac{a\dot{M}}{u} \times u \times \overline{\int \frac{dr^2}{a^2}\Big|}^{\frac{1}{2}}}{\sqrt{n} \times \sqrt{2AM - M^2}} = \frac{a\dot{M} \times \frac{1}{a} \times \overline{\int dr^2\Big|}^{\frac{1}{2}}}{\sqrt{n} \times \sqrt{2AM - M^2}}$$

$$= \frac{\dot{M} \times \overline{\int dr^2\Big|}^{\frac{1}{2}}}{\sqrt{n} \times \sqrt{2AM - M^2}}.$$

Therefore, since $\dot{t} = \frac{a\dot{M}}{u}$, we shall have

On the Force of Torsion.

$$\dot{t} = \frac{\dot{M} \times \overline{\int dr^2\Big|}^{\frac{1}{2}}}{\sqrt{n} \times \sqrt{2AM - M^2}}, \text{ or}$$

$$\dot{t} = \frac{\dot{M}}{\sqrt{2AM - M^2}} \times \overline{\int \frac{dr^2}{n}\Big|}^{\frac{1}{2}}.$$

But $\frac{\dot{M}}{\sqrt{2AM - M^2}}$ represents an arch or angle whose radius is A, and whose versed sine is M, which arch vanishes when M = 0, and which becomes equal to 90° when M = A. Therefore the time of a complete oscillation will be

$$T = \overline{\int \frac{pr^2}{n}\Big|}^{\frac{1}{2}} \times 180°.$$

In order to compare the force of torsion with the force of gravity in a pendulum, we have for the time T of a complete oscillation of a pendulum whose length is l, g being the force of gravity,

$$T = \overline{\frac{l}{g}\Big|}^{\frac{1}{2}} 180°.$$

Therefore, since the time in which the cylinder oscillates must be equal to the time in which the pendulum oscillates, we have

$$\overline{\int \frac{pr^2}{n}\Big|}^{\frac{1}{2}} 180° = \overline{\frac{l}{g}\Big|}^{\frac{1}{2}} \times 180°.$$

Hence, dividing by 180°, and squaring both sides, we obtain

$$\overline{\int \frac{pr^2}{n}\Big|} = \frac{l}{g}.$$

We must therefore find for a cylinder the value of $\int pr^2$, or the sum of all the particles multiplied by the squares of their distances from the axis. Now, if we make π = 6·28318 the ratio of the circumference of a circle to its radius, a = radius of the cylinder, λ = its length, d = its density; then we shall have for the area of its base $\frac{a^2\pi}{2}$, which, multiplied by λ, gives the solid content of the cylinder = $\frac{a^2\pi\lambda}{2}$, and this multiplied by d gives $\frac{a^2\pi\lambda d}{2}$ for the sum of all its particles. But as this is to be multiplied by the sum of the squares of all the distances of the particles from the centre C, we shall have $\int pr^2 = \frac{a^4\pi^2\lambda d}{4}$. But the number of particles in the cylinder, or the mass μ of the cylinder, is $\frac{a^2\pi\lambda d}{2}$, therefore, substituting μ instead of this value of it in the preceding equation, we have $\int pr^2 = \frac{\mu a^2}{2}$, and, dividing both sides by n, we have $\frac{\int pr^2}{n} = \frac{\mu a^2}{2n}$, and, extracting the square root, and multiplying by 180, it becomes

$$\overline{\frac{\int pr^2}{n}\Big|}^{\frac{1}{2}} \times 180° = \overline{\frac{a^2}{2n}\Big|}^{\frac{1}{2}} \times 180°.$$ Therefore

$$T = \overline{\frac{\mu a^2}{2n}\Big|}^{\frac{1}{2}} \times 180;$$

and since $\int \frac{pr^2}{r} = \frac{l}{g}$, $\frac{\mu a^2}{2n} = \frac{l}{g}$, and, by reduction, $n = \frac{g\mu a^2}{2l}$. But $g\mu$ is the weight W of the cylinder, there-

On the Force of Torsion.

fore, by substituting W instead of $g\mu$, we obtain $n = \frac{Pa^2}{2l}$, a very simple formula for determining the value of n from experiments.

If it were required to find a weight Q, which, acting at the extremity of a lever L, would have a momentum equal to the momentum of the force of torsion when the angle of torsion is A — M, we must make $Q \times L = n \times \overline{A-M}$.

In the preceding investigation we have supposed, what is conformable to experiment, that the force of torsion is proportional to the angle of torsion, which gives us $n \times \overline{A-M}$ for the momentum of that force. Let us now suppose that this momentum is altered by any quantity S, then the momentum of the force of torsion will become $n \times \overline{A-M} - S$ and the general equation will assume this form,

$$n \times A - M - S \times \dot{t} = \dot{u} \int \frac{pr^2}{a};$$

and, by substituting in place of $\dot{t}$ its value $\frac{a\dot{M}}{u}$, and taking the fluent, we have

$$\overline{n \times 2AM - M^2} - 2\int S\dot{M} = u^2 \int \frac{dr^2}{a^2}.$$

Now, in order to find the value of T or a complete oscillation, we must divide the oscillation into two parts, the first from B to A, where the force of torsion accelerates the velocity u, while the retarding force, arising from the resistance of the air and the imperfection of elasticity, diminishes the velocity u; and the second from A to B′, where the force of torsion, as well as the other forces, concur in diminishing u or retarding the motion.

Ex. 1. If $S = m \times \overline{A-M}^{\nu}$, we shall have for the state of motion in the first portion BA

$$n \times \overline{2AM - M^2} + \frac{2M \times \overline{A-M}^{\nu+1}}{\nu+1} - \frac{2mA^{\nu+1}}{\nu+1} = u^2 \int \frac{pr^2}{a^2}.$$

Hence, when the angle of torsion becomes equal to nothing, or $A - M = 0$, we have

$$nA^2 - \frac{2mA^{\nu+1}}{\nu+1} = UU \int \frac{pr^2}{a^2},$$

which, dividing by $\int \frac{pr^2}{a^2}$, becomes

$$U^2 = \frac{nA^2 - \frac{2mA^{\nu+1}}{\nu+1}}{\int \frac{r^2}{a^2}}.$$

Let us now consider the other part of the motion from A to B′, and suppose the angle $ACb' = M'$, we shall find, by calling U the velocity of the point A,

$$\frac{nM'^2}{2} + \frac{mM'^{\nu+1}}{\nu+1} = \frac{U^2 - u^2}{2} \times \int \frac{pr^2}{a^2}.$$

Then, by substituting instead of U its value as lately found, and taking the fluents, we shall have, when the velocity vanishes, or when the oscillation is finished,

$$A - M' = \frac{2m}{n \times \overline{\nu+2}} \times \frac{A^{\nu+1} + M'^{\nu+1}}{A + M'};$$

and if the retarding forces are such that at each oscillation the amplitude is a little diminished, we shall have for the approximate value of A — M′

$$A - M' = \frac{2mA^{\nu}}{n \times \overline{\nu+1}},$$

and if the angle A — M′ is so small that it may be treated as a common fluxional quantity, we shall then have for any number of oscillations

$$N \times \frac{2m}{n \times \overline{\nu+1}} = \frac{1}{\nu-1} \times \frac{1}{M^{\nu-1}} - \frac{1}{A^{\nu-1}},$$

where M represents the angle to which A becomes equal after any number of oscillations N. Hence we obtain

$$M = \frac{1}{\left(N \times \frac{2m \times \overline{\nu+1}}{n \times \nu+1} + \frac{1}{A^{\nu-1}}\right) \times \frac{1}{\nu-1}},$$

which determines the value of M after any number of oscillations N.

Ex. 2. If $S = m \times \overline{A-M}^{\nu} + m' \times \overline{A-M}^{\nu'}$, m' and ν' being different values of m and ν, we shall obtain, by following the mode of investigation in the last example,

$$n \times A - M = \frac{2m}{\nu+1} \times \frac{A^{\nu+1} + M^{\nu+1}}{A+M} \times \frac{2m'}{\nu'+1} \times \frac{A^{\nu'+1} \times M^{\nu'+1}}{A+M};$$

and if the retarding force is much less than the force of torsion, we shall have for an approximate value of

$$n \times \overline{A-M} = \frac{2mA^{\nu}}{\nu+1} + \frac{2m'A^{\nu'}}{\nu'+1}.$$

Ex. 3. In general, if $S = m \times \overline{A-M}^{\nu} + m' \times \overline{A-M}^{\nu'} + m'' \times \overline{A-M}^{\nu''} + m''' \times \overline{A-M}^{\nu'''}$, &c. we shall always have for an oscillation, when S is smaller than the force of torsion,

$$n \times \overline{A-M} = \frac{2mA^{\nu}}{\nu+1} + \frac{2m'A^{\nu'}}{\nu'+1} + \frac{2m''A^{\nu''}}{\nu''+1} + \frac{2m'''A^{\nu'''}}{\nu'''+1}, \text{ &c.}$$

Having thus given, after Coulomb, the mode of deducing formulæ for the oscillatory motion of the cylinder, we shall proceed to give an account of the results of his experiments.

Torsion balance.

In these experiments M. Coulomb employed the torsion balance represented in fig. 101, in which he suspended cylinders of different weights from iron and brass wires of different lengths and thicknesses; and, by observing carefully the duration of a certain number of oscillations, he was enabled to determine, by means of the preceding formulæ, the laws of the force of torsion relative to the length, the thickness, and the nature of the wires employed. If the elasticity of the metallic wires had been perfect, and if the air opposed no resistance to the oscillating cylinder, it would continue to oscillate till its motion was stopped. The diminution of the amplitudes of the oscillations, therefore, being produced solely by the imperfection of elasticity, and by the resistance of the air, M. Coulomb was enabled, by observing the successive diminution of the amplitude of the oscillation, and by subtracting the part of the change which was due to the resistance of the air, to ascertain, with the assistance of the preceding formulæ, according to what laws this elastic force of torsion was changed.

These experiments were made with iron and brass wires of the kind described in the following table:—

Nature of the Wires.	No. of the Wires in Commerce.	Weight in Grains, of Six Feet of each Wire.	Weight under which the Wires broke. lbs. oz.
Iron harpsichord wires,	12	5	3 0
	7	14	10 0
	1	56	33 0
Brass wires,	12	5	2 3
	7	18·5	14 0
	1	66	22 0

These wires were fixed one after another on the torsion balance, shown in fig. 101, and were made to suspend cylinders nineteen lines in diameter, and of different weights. The circumstances under which the experiments were made, and the results which Coulomb obtained, are given in the

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following table. The angles of torsion were always so small that the particles of the twisted wires returned to their original state. This was not the case, however, at angles greater than those in the table.

Nature of the Wires.	No. of the Wires in Commerce.	Length of Wires, in Inches.	Weight of Suspended Cylinder, in Pounds.	Limit of the Centre of Torsion for Isochronous Oscillations.	Time of Twenty Isochronous Oscillations.
Harpsichord iron wire,	12	9	0·5	180°	120″
	12	9	2·0	180	242
	7	9	0·5	180	42
	7	9	2·0	180	85
	1	9	2·0	45	23
Brass wires,	12	9	0·5	360	220
	12	9	2·0	360	442
	7	9	0·5	360	57
	7	9	2·0	360	110
	7	36	2·0	1080	222
	1	9	2·0	50	32

As the twenty oscillations of the cylinder were in these experiments sensibly isochronous, Coulomb considered the supposition on which the preceding formulæ are founded, as a fundamental law, *that in all metallic wires*, when the *angles of torsion are not very great, the force of torsion is sensibly proportional to the angle of torsion;* and hence the formulæ may be safely used in the discussion of the experiments.

It appears from the first and second, third and fourth, seventh and eighth, and ninth and tenth experiments, that when the suspended weight was *two* pounds, the oscillations were performed in the times

242″, 85″, 442″, and 110″,

while with weights of half a pound the times were

120″, 43″, 220″, and 57″,

which are nearly one half of the former. But $1 : 2 = \sqrt{\frac{1}{2}} : \sqrt{2}$. Consequently *the durations of the oscillations are proportional to the square roots of the suspended cylinders.* Hence it appears that the different degrees of tension produced by the different weights used in these experiments has no sensible influence on the re-action of the force of torsion.

If we vary the lengths of the wires without changing their diameters, or the suspending weights, as in experiments ninth and tenth, where the lengths are as 9 to 36, or 1 : 4, and the times 110″ and 222″, or as 1 : 2, it follows that *the times of the same number of oscillations are as the square roots of the lengths of the wires*, as the theory indicates.

When the diameters of the wires are varied without changing their lengths, or the weight of the cylinders, the momentum of the force of torsion varies *as the fourth power of the diameters of the wires.* Now this result is perfectly conformable to theory; for if we suppose two wires of the same substance and of the same length, but having their diameters as one to two, it is obvious, that in the wire whose diameter is double that of the other, there are four times as many parts extended by torsion as in the smaller wire, and that the mean extension of all these parts will be proportional to the diameter of a wire, the same as the mean arm of a lever is relative to the axis of rotation. Hence it appears that, according to theory, the force of torsion of two wires of the same nature and of the same length, but of different diameters, is proportional to the fourth power of their diameter.

From this it follows in general, that in metallic wires the *momentum of torsion is directly in the compound ratio of the angle of torsion and the fourth power of their diameter, and inversely as the length of the wires.* If a, therefore, be the angle of torsion, λ the length of the thread, δ its diameter, and F the force of torsion, we shall have

$$F = \frac{ma\delta^4}{l},$$

where m is a constant co-efficient for wires of the same metal, depending on the tenacity of the metal, and deducible from experiment.

When the angle of torsion is not great relative to the length of the wire, the index of the cylinder returns to the position which it had before the torsion took place, or, in other words, the wire untwists itself by the same quantity by which it had been twisted. But when the angle of torsion is very great, the wire does not completely untwist itself, and therefore the centre of torsion will have advanced by a quantity equal to that which it has not untwisted. If the angle of torsion, for example, is 180°, and if after the oscillations have ceased the index returns only 170° in place of 180°, the centre of torsion is said to have advanced 10°, or to be displaced by that quantity.

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In his experiments on this subject, M. Coulomb used the iron wire No. 1, $6\frac{1}{2}$ inches long, and supporting a weight of two pounds. The following were his results:—

Angles of Torsion.	No. of Oscillations.	Degrees Lost.
90°	$3\frac{1}{2}$	10°
45	$10\frac{1}{2}$	10
$22\frac{1}{2}$	23	10
$1\frac{1}{4}$	46	10

When the wire was twisted through a greater angle than 90°, the centre of torsion suffered a displacement which increased with the angle of torsion, as shown in the following table:—

Angles of Torsion.	Angle through which the Wire untwists itself.	Successive Displacement of the Centre of Torsion.	Total Displacement.
$\frac{1}{2}$ a circle	172°	8°	8°
1 circle	310	50	58
2 ...	410	310	1 circle + 8
3 ...	420	1 circle + 300	2 ... + 308
4 ...	430	2 ... + 290	5 ... + 238
5 ...	440	3 ... + 280	9 ... + 158
6 ...	460	4 ... + 260	14 ... + 58
10 ...	480	8 ... + 240	22 ... + 298

14 wire split longitudinally.

In this table the first column contains the angle through which the index has been turned, the second shows the angle through which the wire has untwisted itself. The differences between the first column and the second constitute the third column, which shows the angle which the wire wanted of returning to its primitive state, or the displacement of the centre of torsion at each successive experiment. The fourth column shows the total displacement of the centre of torsion, and is obtained by adding any one displacement in column 3 to all that precede it.

From these experiments it appears that for angles of torsion below 45°, the decrements of the amplitudes of the oscillations were nearly proportional to the amplitudes of the angles of torsion, and that when the angles exceeded 45°, the decrements increased in a much greater ratio. From the results in the second table, it appears that the centre of torsion did not begin to advance or be displaced till the angle of torsion was nearly 180°; that this displacement increases in proportion as the thread is twisted; that it is irregular till the angle of torsion is 310°; and that for greater angles the re-action of torsion remained nearly the same for all angles of torsion.

From these and other experiments, which our limits will not permit us to give, Coulomb has deduced the following theory of elasticity and cohesion in metals.

Coulomb's theory of elasticity and cohesion in metals.

In all metallic wires the forces necessary for compressing or dilating the integrant particles are proportional to the compressions or the dilatations they experience, or their elasticity is perfect. Cohesion, however, which is different from elasticity, unites these particles together. In small torsions, when the twisting force is less than that of cohesion, the integrant particles are elongated or compressed without any change of place in the points by which they adhere. But when the torsions are so great that the force of compression or dilatation is equal to the cohesion of the

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particles, these particles ought to separate, or slide upon one another. This sliding of the particles takes place in all ductile bodies; but if by this cause the body is compressed, the extent of the points of contact and the extent of the field of elasticity become greater. As the particles have a given figure, the extent of the points of contact cannot augment but to a certain degree, at which the body breaks.

In confirmation of this theory, Coulomb made the following experiment, in which he varied the cohesion without changing the elasticity. A copper wire which broke with 22 lbs. was brought to the temper of a white heat, which reduced its cohesion so much that it could scarcely support 12 or 14 lbs. The two wires, however, when twisted through the same angle by the same weight, performed the same number of oscillations in the same time, though the cohesion was only half as great in the one wire as in the other, and the amplitude of elasticity diminished in the same proportion.

Coulomb confirmed these views by some ingenious experiments on the flexion of steel plates in different states with respect to cohesion, and he extends his views of the constitution of metals to all bodies whatever. Their integrant particles have always a perfect elasticity; but bodies are hard, soft, or fluid, according to the cohesion of these particles. If they can slide upon one another, as in hard bodies, without any sensible change of distance, the body will be ductile or malleable; but if they cannot thus slide without their distance being sensibly altered, the body will break when the compressing or dilating force is equal to the cohesion.

The resistance of solid bodies had never undergone that careful investigation which its importance demanded. Mr R. Bevan, however, has supplied in a great measure this defect, by a very complete series of frequently-repeated experiments on woods and metals.[1] The following table contains the results of his experiments.

Table showing the Modulus of Torsion in Woods.

Species of Wood.	Specific Gravity of Wood.	Modulus of Torsion.	Remarks.
Acacia	·795	28293	Not quite dry.
Alder	·55	16221	Cross grained.
Apple	·726	20397	
Ash		20300	Planted by Mr Bevan.
Ash, Mountain	·449	13933	
Beech		21243	
Birch		17250	
Box	·99	30000	Old and very dry.
Brazil wood	1·05	37800	Old and very dry.
Cane		21500	Influenced by the hard surface.
Cedar, scented		12500	
Cherry	·71	22800	
Chestnut, sweet		18360	
Chestnut, horse	·615	22205	
Crab	·763	22738	
Damson		23500	
Deal, Christiana	·38	11220	
Elder	·755	22285	
Elm		13500	
Fir, Scotch		13700	
Hazel	·83	26325	Not quite dry.
Holly		20543	
Hornbeam	·86	26411	Not quite dry.
Laburnum		18000	Green, or fresh cut.
Lancewood	1·01	25245	
Larch	·58	18967	
Lime or Linden	·675	18309	
Maple	·735	23947	Partly cross grained.
Oak, English		20000	
—— Hamburg	·693	12000	
—— Dantzic	·586	16500	
—— from Bog	·67	14500	
Ozier		18700	
Pear	·72	18115	
Pine, St Petersburg		10500	Fresh.
—— ——		13000	Four or five years old.
—— Memel		15000	
—— American		14750	
Plane	·59	17617	
Plum	·79	23700	
Poplar	·333	9473	
Satin wood	1·02	30000	
Sallow		18600	
Sycamore		22300	
Teak		16800	Old, and partially decayed.
—— African		27300	
Walnut		19784	

Mr Bevan has given the following formula for finding the deflection D, or the quantity of twisting, in inches and decimals, viz. $D = \frac{r^2lw}{d^4T}$, l being the length of a prismatic shaft strained by a given weight or force w in pounds avoirdupois, acting at right angles to the axis of the prism, and by a given leverage $= r$, the side of the square shaft being $= d$, and T being the modulus of torsion as given in the preceding table, l, r, D, and d being all in inches and decimals. If the section of the prism is a rectangle whose breadth is b and depth d, then the formula becomes $D = \frac{(d+b)lr^2w}{2bd^3T}$. If an angular measure of the torsion is required, let Δ be the number of degrees, $\varrho = 57{\cdot}29578$, then $\Delta = \frac{r\varrho lw}{d^4T}$; or if $T\varrho = t$, then $\Delta = \frac{rlw}{d^4t}$. Thus, for wrought iron and steel, $\Delta = \frac{rlw}{31000d^4}$, and for cast iron, $\Delta = \frac{rlw}{16600d^4}$.

In exemplifying the application of the first formula, Mr Bevan takes a square shaft of English oak fifty inches long and six inches by six inches, subject to a strain of 3000 lbs. at the circumference of a wheel two feet in diameter, or having a leverage of twelve inches; then $r = 12$, $l = 50$, $w = 3000$, $d = 6$, and $T = 20000$; then we shall have $D = 0{\cdot}83$, or about $\frac{5}{6}$ths of an inch. If the weight or force w were 300 lbs., then, as the deflection is directly as the force, the deflection will be $\frac{1}{12}$th of an inch.

Mr Bevan observed, in a great many of his experiments, that the modulus of torsion bears a close relation to the weight of the wood when dry, whatever be the kind of wood employed; and he has given the following formula for determining the deflection D from the specific gravity $D = \frac{r^2lw}{30000d^4s}$. The amount of deflection thus obtained he considers sufficiently near the truth for practical purposes.

The following are Mr Bevan's results for metals:

Table of the Modulus of Torsion for Metals.

	Specific Gravity.	Modulus of Torsion.
Iron, wrought, English.....	—	1810000
Iron, wrought, English.....	—	1740000
Iron, thin hooping.....	—	1916000
Steel.....	—	1984000
Steel.....	—	1648000
Steel.....	—	1618000
Iron, cylindrical.....	—	1910000
Iron, cylindrical.....	—	1700000

[1] Phil. Trans. 1829, p. 127–132; or Edinburgh Journal of Science, vol. i. p. 340, New Series.

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	Specific Gravity.	Modulus of Torsion.
Iron, square	—	1617000
Iron, square	—	1667000
Iron, square	—	1951000
Mean of iron and steel	—	1779090
Cast iron	—	940000
Cast iron	—	963000
Cast iron	—	952000
Mean of cast iron	7·163	951600
Bell metal	8·531	818000

By comparing the numbers in the preceding table with the modulus of elasticity of the same metals, Mr Bevan has found that the modulus of torsion is *one sixteenth* of the modulus of elasticity in metals.

The theory of torsion is particularly useful in delicate researches, where small forces are to be ascertained with a precision which cannot be obtained by ordinary means. It has been successfully employed by Coulomb in discovering the laws of the forces of electricity and magnetism, and in determining the resistance of fluids when the velocities are very small. Its application to these purposes will be found in our articles on ELECTRICITY, HYDRODYNAMICS, and MAGNETISM.

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PART II.—ON THE CONSTRUCTION OF MACHINERY.

We have already stated, when considering the maximum effects of machines, the various causes which affect their performance. It appeared from that investigation, that there must be a certain relation between the velocities of the impelled and working points of a machine, or between the power and the resistance to be overcome, before it can produce a maximum effect, and therefore it must be the first object of the engineer to ascertain that velocity, and to employ it in the construction of his machine. The performance of the machine is also influenced by the friction and inertia of its various parts; and as both these act as resistances, and therefore destroy a considerable portion of the impelling power, it becomes an object of great importance to attend to the simplification of the machinery, and to ascertain the nature of friction, so as to diminish its effect, either by the application of unguents or by mechanical contrivances. Since the impelled and working points of a machine are generally connected by means of toothed wheels, the teeth must be formed in such a manner that the wheels may always act upon each other with the same force, otherwise the velocity of the machine will be variable, and its structure soon injured by the irregularity of its motion. The irregular motion of machines sometimes arises from the nature of the machinery, from an inequality in the resistance to be overcome, and from the nature of the impelling power. In large machines, the momenta of their parts are generally sufficient to equalize these irregularities; but in machines of a small size, and in those where the irregularities are considerable, we must employ fly-wheels for regulating and rendering uniform their variable movements. These various subjects, and others intimately connected with them, we shall now proceed to discuss in their order.

CHAP. I.—ON THE PROPORTION BETWEEN THE VELOCITY OF THE IMPELLED AND WORKING POINTS OF MACHINES, AND BETWEEN THE POWER AND RESISTANCE, IN ORDER THAT THEY MAY PERFORM THE GREATEST WORK.

In the chapter on the maximum effect of machines we have deduced formulæ containing x and y, the velocities of the impelled and working points of the machines, and including every circumstance which can affect their motion. The formula which exhibits the value of y, or the velocity of the working point, assumes various forms, according as we neglect one or more of the elements of which it is composed. When the work to be performed resists only by its inertia, which is the case in urging round a millstone or heavy fly, the quantity R may be neglected, and the second formula (page 393, col. 2) should be employed. In small machines, and particularly in those where the motion is conveyed by wheels with epicycloidal teeth, the friction is very trifling, and the element φ may be safely omitted. In corn and saw mills, the quantity b, or the inertia of the resistance, may be left out of the formula, as the motion communicated to the flour or to the saw-dust is too small to be subjected to computation. In machines where one heavy body is employed to raise another merely by its weight, the inertia of the power and the resistance, viz. a, b, are proportional to P, R, the powers and resistances themselves, and consequently P, R may be substituted in the formula in the place of a, b. The engineer therefore must consider, before he construct his machine, what elements should enter into the formula, and what should be omitted, in order that he may adapt it to the circumstances of the case, and obtain from his machine the greatest possible effect.

To find the relation between the velocities of the impelled and working points of a machine.

When the inertia of the power and that of the resistance are proportional to the power and resistance themselves, and when the inertia and friction of the machine may be omitted, the formula becomes $y = \sqrt{\left|\frac{P}{R} + 1\right|} - 1$; from which the following table is computed, which contains the values of y for different values of P; R being supposed $= 10$, and $m = 1$.

Table containing the best Proportions between the Velocities of the Impelled and Working Points of a Machine, or between the Levers by which the Power and Resistance act.

Proportional Value of the Impelling Power, or P.	Value of the Velocities of the Working Point, or y; or of the Lever by which the resistance acts, that of x being 1.	Proportional Value of the Impelling Power, or P.	Value of the Velocities of the Working Point, or y; or of the Lever by which the resistance acts, that of x being 1.
1	0·048809	20	0·732051
2	0·095445	21	0·760682
3	0·140175	22	0·788854
4	0·183216	23	0·816590
5	0·224745	24	0·843900
6	0·264911	25	0·870800
7	0·303841	26	0·897300
8	0·341641	27	0·923500
9	0·378405	28	0·949400
10	0·414214	29	0·974800
11	0·449138	30	1·000000
12	0·483240	40	1·236200
13	0·516575	50	1·449500
14	0·549193	60	1·645700
15	0·581139	70	1·828400
16	0·612451	80	2·000000
17	0·643168	90	2·162300
18	0·673320	100	2·316600
19	0·702938		

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In order to explain the use of this table, let us suppose that it is required to raise one cubic foot of water in a second, by means of a stream which discharges three cubic feet of water in a second; and let it be required to find the construction of a wheel and axle for performing this work; that is, the diameter of the axle, that of the wheel being 6. Here the power is evidently three cubic feet, while the resistance is only one cubic foot, therefore $P = 3\ R$; but in the preceding table $R = 10$, consequently $P = 3 \times 10 = 30$. But it appears from the table that when $P = 30$, y or the diameter of the axle is 1, upon the supposition that the diameter x of the wheel is 1; but as x must be $= 6$, we shall have $y = 6$.

Instead of using the preceding table, we might find the best proportion between x and y by a kind of tentative process, from the formula $\frac{P\,x\,Ry - R^2y^2}{Px^2 + R\,y^2}$, which expresses the work performed. This method is indeed tedious; and we mention it only for the sake of showing the conformity of the results, and of proving that there is a certain proportion between x and y which gives a maximum effect. Let $x = 6$, as in the preceding paragraph, and let us suppose y to be successively 5, 6, and 7, in order to see which of these values is the best. Since $P = 3$, $R = 1$, and $x = 6$, we have,

$$\text{When } y = 5,\ \frac{PxRy - R^2y^2}{Px^2 + Ry^2} = \frac{3 \times 6 \times 1 \times 5 - 1 \times 5 \times 5}{3 \times 6 \times 6 + 1 \times 5 \times 5} = \frac{65}{133} = 0{\cdot}488;$$

$$\text{When } y = 6,\ \frac{PxRy - R^2y^2}{Px^2 + Ry^2} = \frac{3 \times 6 \times 1 \times 6 - 1 \times 6 \times 6}{3 \times 6 \times 6 + 1 \times 6 \times 6} = \frac{72}{144} = 0{\cdot}500;$$

$$\text{When } y = 7,\ \frac{PxRy - R^2y^2}{Px^2 + Ry^2} = \frac{3 \times 6 \times 1 \times 7 - 1 \times 7 \times 7}{3 \times 6 \times 6 + 1 \times 7 \times 7} = \frac{77}{157} = 0{\cdot}49045.$$

It appears, therefore, that when $y = 5, 6, 7$, the work performed is 0·488, 0·5000, 0·49045; so that the effect is a maximum when $y = 6$, a result similar to what was obtained from the table.

To find the best proportion between the power and the resistance.

When the machine is already constructed, x and y cannot be varied so as to obtain a maximum effect. The same object, however, will be gained by properly adjusting the power to the work when the work cannot be altered, or the work to the power when the power is determinate. The formulæ in Prop. II. Chap. VII. exhibit the values of R under many circumstances, and it depends on the judgment of the engineer to select such of them as are adapted to all the conditions of the case.

The following table is founded on the formula $R = \sqrt{\frac{y+1}{y^2}} - \frac{1}{y^2}$, which answers to the case where the inertia of the impelling power is the same with its pressure, and where the inertia and the friction of the machine may be safely neglected. The second column contains the different values of R corresponding to the values of y in the first column. The numbers in the third column show the ratio of y to R, or they have the same proportion to 1 which R has to the resistance which will balance P. In the table it is supposed that $P = 1$ and $x = 1$.

Table containing the best Proportions between the Power and the Resistance, the Inertia of the Impelling Power being the same with its Pressure, and the Friction and Inertia of the Machine being omitted.

Values of y, or the Velocity of the Working Point, x being equal to 1.	Values of R, or the resistance to be overcome, P being = 1.	Ratio of R to the resistance which would balance P.	Values of y, or the Velocity of the Working Point, x being equal to 1.	Values of R, or the resistance to be overcome, P being = 1.	Ratio of R to the resistance which would balance P.
$\frac{1}{4}$	1·8885	0·4724 to 1	7	0·03731	0·26117 to 1
$\frac{1}{3}$	1·3928	0·4639 ...	8	0·03125	0·25000 ...
$\frac{1}{2}$	0·8986	0·4493 ...	9	0·02669	0·24021 ...
1	0·4142	0·4142 ...	10	0·02317	0·23170 ...
2	0·1830	0·3660 ...	11	0·02037	0·22407 ...
3	0·1111	0·3333 ...	12	0·01809	0·21708 ...
4	0·0772	0·3088 ...	13	0·01622	0·21086 ...
5	0·0580	0·2900 ...	14	0·01466	0·20524 ...
6	0·0457	0·2742 ...	15	0·01333	0·19995 ...

To exemplify the use of the preceding table, let us suppose that we are to raise water by means of a simple pulley and bucket, with a power = 10, and that it is required to find the resistance R, or the quantity of water which must be put into the bucket, in order that the work performed may be a maximum. In the simple pulley x, y, the arms of the vertical levers, or the velocities of the impelled and working points, are equal; and since x is supposed in the table to be = 1, we have $y = 1$, which corresponds in the table with 0·4142, the value of R, P being = 1 in the table: but in the present case P = 10, therefore 10 : 1 = 0·4142 : 4·142, the value of R when P = 10.

The same result might be obtained in a more circuitous method by means of the formula $\frac{PxRy - R^2y^2}{Px^2 + R^2y^2}$, which expresses the performance of the machine. Thus, let $x = 1$; $y = 1$; P = 10, and let us suppose R successively equal to 3, 4, 4·142, 5; so that we may determine which of these values gives the greatest performance.

$$\text{When R} = 3, \text{ the preceding formula becomes } \frac{\overline{10 \times 3} - \overline{3 \times 3}}{10 + 3} = \frac{21}{13} = 1{\cdot}6154.$$

$$\text{When R} = 4, \text{ the formula becomes } \frac{\overline{10 \times 4} - \overline{4 \times 4}}{10 + 4} = \frac{24}{14} = 1{\cdot}7143.$$

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When $R = 4{\cdot}142$, the formula becomes $\frac{\overline{10 \times 4{\cdot}142} - \overline{4{\cdot}142}^2}{10 \times 4{\cdot}142} = \frac{24{\cdot}26384}{14{\cdot}142} = 1{\cdot}7157.$

When $R = 5$, the formula becomes $\frac{10 \times 5 - 5 \times 5}{10 + 5} = \frac{25}{15} = 1{\cdot}6666.$

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Hence it appears, that when $R = 3, 4, 4{\cdot}142, 5$, the work performed is respectively $= 1{\cdot}6154, 1{\cdot}7143, 1{\cdot}7157, 1{\cdot}6666$; so that the work performed is a maximum when R is $= 4{\cdot}142$, the same result which was obtained from the table.

CHAP. II.—ON THE SIMPLIFICATION OF MACHINERY.

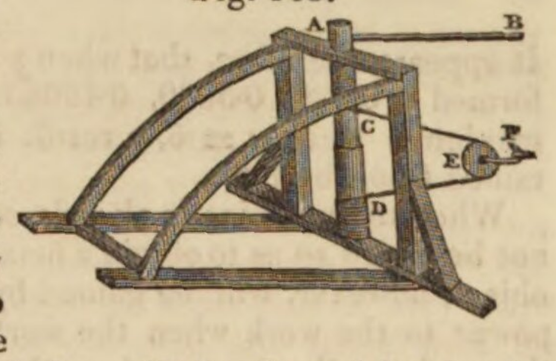
As the inertia of every machine adds greatly to the resistance to be overcome, and as the friction of the communicating parts is proportional to the pressure, it becomes a matter of great practical importance, that the different parts of a machine should be proportioned to the strains to which they are exposed. If the beam of a steam-engine, for example, is larger than what is necessary, an immense portion of the impelling power must be destroyed at every stroke of the piston, by dragging the superfluous mass from a state of rest into motion; the pressure upon the gudgeons will also be increased, and their friction in their sockets proportionally enlarged. The engineer, therefore, should be well acquainted with the strength of the materials of which the machine is to be constructed, and should frame its different parts in such a manner that they may not be heavier than what is necessary for resisting the forces with which they are urged. When the motions of the machine are necessarily irregular, and when the machine may be exposed to accidental strains, the parts must be made considerably stronger than what is necessary for resisting its ordinary strains; but it is not often that such a precaution should be observed. The gudgeons of water-wheels, and of the beams of steam-engines, ought to be made as short and small as possible, as the friction increases with the rubbing surfaces. This is very seldom attended to in the construction of water-wheels. The diameter of the gudgeons is frequently thrice as large as what is necessary for supporting the weight of the wheel.

In the construction of machinery we must not only attend to the simplification of the parts, but also to the number of these parts, and the mode of connecting them. From the nature and quantity of the work to be performed, it is easy to ascertain the velocity of the working point which is most proper for performing it. Now this velocity may be procured in a variety of ways, either by a perplexing multiplicity of wheels, or by more simple combinations. The choice of these combinations must be left solely to the judgment of the engineer, as no general rules can be laid down to direct him. It may be useful, however, to remark, that the power should always be applied as near as possible to the working point of the machine, and that when one wheel drives another, the diameter of the one should never be great when the diameter of the other is very small. The size of wheels is often determined from the strains to which they are exposed. If, for example, we are obliged to give a certain velocity to an axle by means of a wheel with 120 teeth, and if the force with which this wheel is urged requires the teeth to be at least one inch thick in order to prevent them from breaking, we shall be obliged to make its diameter at least seven feet; for supposing the spaces between the teeth to be equal to the thickness of the teeth, the circumference of the wheel must at least be equal to $120 + 120 = 240$ inches, the sum of the teeth and their intervals, which gives a diameter of six feet eight inches. There are some cases where our choice of combination must be directed by the nature of the machinery. If the work to be performed is a load raised with a certain velocity by means of a rope winding round a hollow drum, and if the simplest combination of mechanical powers for producing this velocity should give a small diameter to the drum, then this combination must give way to another which corresponds with a larger size of the drum; for, on account of the inflexibility of the ropes, a great portion of the impelling power would be wasted in winding them about the circumference of a small drum.

Description of a powerful capstan.

The advantages of simplifying machinery are well exemplified in the following capstan, which unites great strength and simplicity. It is represented in fig. 103, where AD is a compound barrel composed of two cylinders of different radii. The rope DEC is fixed at the extremity of the cylinder D; and after passing over the pulley E, which is attached to the load by means of the hook F, it is coiled round the cylinder D, and fixed at its upper end. The capstan bar AB urges the compound barrel CD about its axis, so that while the rope coils round the cylinder D it unwinds itself from the cylinder C. Let us suppose that the diameter of the part D of the barrel is 21 inches, while the diameter of the part C is only 20 inches, and let the pulley E be 20 inches in diameter. When the barrel AD, therefore, has performed one complete revolution by the pressure exerted at B, 63 inches of rope, equal to the circumference of the cylinder, will be gathered upon the cylinder D, and 60 inches will be unwinded from the cylinder C. The quantity of wound rope, therefore, exceeds the quantity that is unwound by $63 - 60 = 3$ inches, the difference of their respective perimeters; and the half this quantity, or $1\frac{1}{2}$ inch, will be the space through which the load or pulley E moves by one turn of the bar. If a simple capstan of the same dimensions had been employed, the length of rope coiled round the barrel would have been 60 inches; and the space described by the pulley, or load to be overcome, would have been 30 inches. Now, as the power is to the weight as the velocity of the weight is to the velocity of the power, and as the velocity of the power is the same in both capstans, the weights which they will raise will be as $1\frac{1}{2}$ to 30. If it is wished to double the power of the machine, we have only to cover the cylinder C with lathes a quarter of an inch thick, so that the difference between the radii of each cylinder may be half as little as before; for it is obvious that the power of the capstan increases as the difference between the radii of the cylinders is diminished. As we increase the power, therefore, we increase the strength of our machine, while all other engines are proportionally enfeebled by an augmentation of power. Were we, for example, to increase the power of the common capstan, we must diminish the barrel in the same proportion, supposing the bar AB not to admit of being lengthened, which will not only diminish its strength, but destroy much of its power by the additional flexure of the rope. This capstan may be easily converted into a crane by giving the compound barrel a horizontal position, and substituting a winch instead of the bar AB. The superiority of such a crane

Fig. 103.



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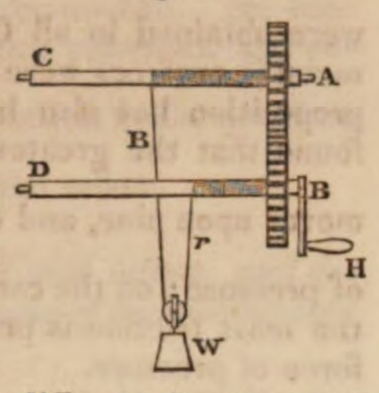
above the common ones does not require to be pointed out; but it has this additional advantage, that it allows the weight to stop at any part of its progress, without the aid of a ratchet-wheel and catch, because the two parts of the rope pull on the contrary sides of the barrel. The rope indeed which coils round the larger part of the barrel acts with a larger lever, and consequently with greater force, than the other; but as this excess of force is not sufficient to overcome the friction of the machine, the weight will remain stationary in any part of its path.

Compound double machine on the same principle.

The principle on which the preceding capstan is constructed might be applied with great advantage when two separate axles AB, CD are driven by means of the winch H and the wheels B and A. It is evident that when the winch is turned round in one direction, the rope R is unwinded from the axle BD; the wheel B drives the wheel A, so that the axle AC moves in a direction opposite to that of BD, and the rope is coiled round the axle AC. If the wheels A, B are of the same diameter and the same number of teeth, the weight W will be stationary, as the rope winded about one axle will be always equal to what is unwinded from the other. If the wheels have different diameters, or different numbers of teeth, the quantity of rope wound round the one axle will exceed what is unwound from the other, and the weight will be raised.

Fig. 104.



CHAP. III.—ON THE LAWS OF FRICTION, THE FRICTION OF AXLES, THE METHOD OF DIMINISHING THE EFFECTS OF FRICTION IN MACHINERY; AND ON THE RIGIDITY OF ROPES.

The friction generated in the communicating parts of machinery opposes such a resistance to the impelling power, and is so injurious to the machine itself, that an acquaintance with the nature and effects of this retarding force, and with the method of diminishing its effects on machinery, is of infinite importance to the practical mechanic.

The subject of friction has been examined at great length by Amontons,[1] Bulfinger,[2] Parent,[3] Euler,[4] and Bossut,[5] and has more recently occupied the attention of the late Mr Vince of Cambridge.

Result of Vince's experiments.

He found that the friction of hard bodies in motion is an uniformly retarding force, and that the quantity of friction considered as equivalent to a weight drawing the body backwards is equal to $M\frac{M+\overline{W\times S}}{gt^2}$, where M is the moving force expressed by its weight, W the weight of the body upon the horizontal plane, S the space through which the moving force or weight descended in the time t, and $g = 16{\cdot}087$ feet the force of gravity. Mr Vince[6] also found that the quantity of friction increases in a less ratio than the quantity of matter or weight of the body, and that the friction of a body does not continue the same when it has different surfaces applied to the plane on which it moves, but that the smallest surfaces will have the least friction.

Experiments of Coulomb.

Notwithstanding the attempts of preceding philosophers to unfold the nature of friction, it was reserved for the celebrated Coulomb[7] to surmount the difficulties which are inseparable from such an investigation, and to give an accurate and satisfactory view of this difficult branch of mechanical philosophy. By employing large bodies, and conducting his experiments on a great scale, he has corrected several errors which arose from the limited experiments of others; he has brought to light many new and striking phenomena, and confirmed others which were hitherto but partially established. As it would be foreign to the nature of this work to follow this ingenious philosopher through his numerous and varied experiments, we shall only present the reader with a description of his apparatus, and an account of the interesting results which he obtained.

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The apparatus used by Coulomb in his experiments on friction, consists of a solid table resting upon very strong

Fig. 105.

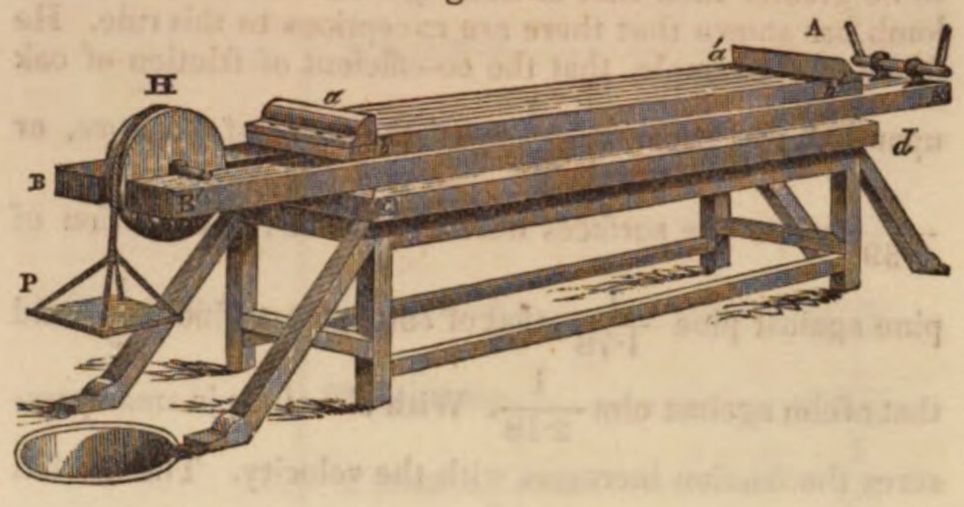
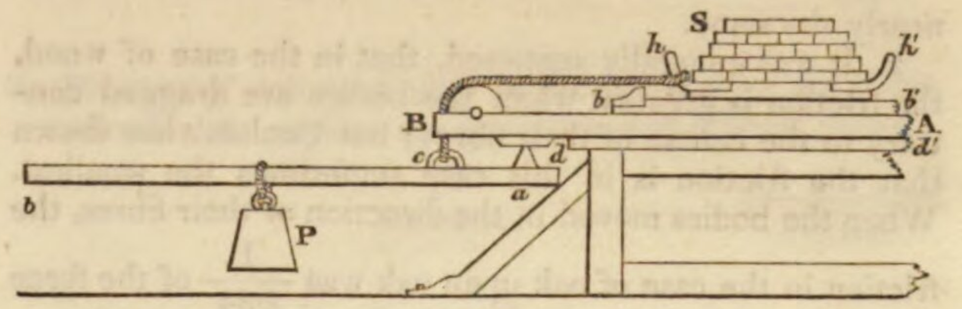
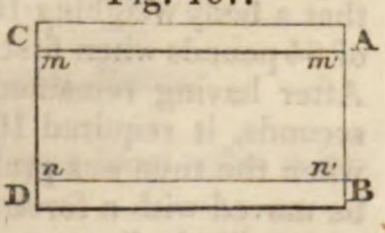


Fig. 106.



legs. The plank *cd*, fig. 105, and *dd'*, fig. 106, which constitutes the table, is eight feet long, two wide, and three inches thick. Two pieces of oak AB, A′B′, twelve feet long and eight inches thick, are placed on the table in the direction of its length, and at the distance of three inches from each other. A pulley H of hard wood, a foot in diameter, and of fourteen pounds weight, is fixed upon an axle of green oak ten lines in diameter, and moving in sockets at the ends B, B′ of the two pieces of oak. A cord passing over this pulley carries at one end a scale P, and is fixed at the other to a sledge S, fig. 106, which runs upon the table. The scale P, for carrying weights, is capable of descending four feet into a pit cut beneath it. A small horizontal wheel and axle is placed at the other ends A, A′ of the pieces of oak AB, A′B. Above these pieces is fixed another plank *aa'bb'*, eight feet long, sixteen inches wide, and three inches thick, having its upper surface smoothly planed. Sledges of the form shown in the annexed figures are made to slide upon this plank. The sledge ABDC, fig. 107, is a plank eighteen inches wide, but having its length variable; and there is nailed beneath it two pieces AC*mm'*, BD*nn'*, so that when this sledge is placed upon the fixed plank *aa'bb'*, it may be retained by these pieces on

Fig. 107.



[1] *Mém. Acad. Paris*, 1699, p. 206.
[2] *Commentar. Petropolitan.* tom. ii. p. 40.
[3] *Recherches de Mathématique et Physique*, 1713, tom. ii. p. 462; and *Mém. Acad. Par.* 1704, p. 174.
[4] *Mém. Acad. Berlin*, 1748, p. 122 and 133.
[5] *Traité Elementaire de Mécanique*, edit. 1802, p. 178.
[6] *Phil. Trans.* vol. lxxv. p. 167.
[7] *Mém. des Savans Etrangers*, tom. ix. and x.; and *Mém. Acad. Par.* 1790, p. 448.

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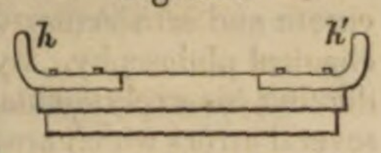
both sides with a play of two or three lines, so that it may move undisturbed in the direction of the plank. When the touching surfaces are required to be smaller, other pieces of different widths are nailed upon the plank ABDC, and their ends rounded for receiving the nuts, to prevent them from rubbing on the plank. To one of the hooks h is fixed the pulley cord, and to the other h the cord which goes round the wheel and axle already mentioned, and the use of which is to bring back the sledge to the side AA′ of the apparatus. In some of the experiments a steel-yard was used, as shown in fig. 106.

Fig. 108.



1. The friction of homogeneous bodies, or bodies of the same kind, moving upon one another, is generally supposed to be greater than that of heterogeneous bodies; but Coulomb has shown that there are exceptions to this rule. He found, for example, that the co-efficient of friction of oak upon oak was equal to $\frac{1}{2{\cdot}34}$ of the force of pressure, or $\frac{1}{2{\cdot}39}$ when the surfaces were very small; the friction of pine against pine $\frac{1}{1{\cdot}78}$, that of oak against pine $\frac{1}{1{\cdot}5}$, and that of elm against elm $\frac{1}{2{\cdot}18}$. With elm alone in small pressures the friction increases with the velocity. The friction of oak against copper was $\frac{1}{5{\cdot}5}$, and that of oak against iron nearly the same.

2. It was generally supposed, that in the case of wood, the friction is greatest when the bodies are dragged contrary to the course of their fibres; but Coulomb has shown that the friction is in this case sometimes the smallest. When the bodies moved in the direction of their fibres, the friction in the case of oak upon oak was $\frac{1}{2{\cdot}34}$ of the force with which they were pressed together; but when the motion was contrary to the courses of the fibres, the friction was only $\frac{1}{3{\cdot}76}$.

3. *The longer the rubbing surfaces remain in contact, the greater is their friction.*—When wood was moved upon wood, according to the direction of the fibres, the friction was increased by keeping the surfaces in contact for a few seconds; and when the time was prolonged to a minute, the friction seemed to have reached its farthest limit. But when the motion was contrary to the course of the fibres, a greater time was necessary before the friction arrived at its maximum. When wood was moved upon metal, the friction did not attain its maximum till the surfaces continued in contact for five or six days; and it is very remarkable, that when wooden surfaces were anointed with tallow, the time requisite for producing the greatest quantity of friction was increased. The increase of friction which is generated by prolonging the time of contact is so great, that a body weighing 1650 pounds was moved with a force of 64 pounds when first laid upon its corresponding surface. After having remained in contact for the space of three seconds, it required 160 pounds to put it in motion; and, when the time was prolonged to six days, it could scarcely be moved with a force of 622 pounds. When the surfaces of metallic bodies were moved upon one another, the time of producing a maximum of friction was not changed by the interposition of olive oil; it was increased, however, by employing swine's grease as an unguent, and was prolonged to five or six days by besmearing the surfaces with tallow.

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4. *Friction is in general proportional to the force with which the rubbing surfaces are pressed together; and is, for the most part, equal to between $\frac{1}{2}$ and $\frac{1}{4}$ of that force.*—In order to prove the first part of this proposition, Coulomb employed a large piece of wood, whose surface contained three square feet, and loaded it successively with 74 pounds, 874 pounds, and 2474 pounds. In these cases the friction was successively $\frac{1}{2{\cdot}46}$, $\frac{1}{2{\cdot}16}$, $\frac{1}{2{\cdot}21}$, of the force of pressure; and when a less surface and other weights were used, the friction was $\frac{1}{2{\cdot}36}$, $\frac{1}{2{\cdot}42}$, $\frac{1}{2{\cdot}40}$. Similar results were obtained in all Coulomb's experiments, even when metallic surfaces were employed. The second part of the proposition has also been established by Coulomb. He found that the greatest friction is engendered when oak moves upon pine, and that it amounts to $\frac{1}{1{\cdot}78}$ of the force of pressure; on the contrary, when iron moves upon brass, the least friction is produced, and it amounts to $\frac{1}{4}$ of the force of pressure.

5. *Friction is in general not increased by augmenting the rubbing surfaces.*—When a superficies of three feet square was employed, the friction, with different weights, was $\frac{1}{2{\cdot}28}$ at a medium; but when a small surface was used, the friction, instead of being greater, as might have been expected, was only $\frac{1}{2{\cdot}39}$.

Friction diminished by increasing the velocity.

6. *Friction for the most part is not augmented by an increase of velocity.* In some cases, *it is diminished by an augmentation of velocity.*—M. Coulomb found, that when wood moved upon wood in the direction of the fibres, the friction was a constant quantity, however much the velocity was varied; but that when the surfaces were very small in respect to the force with which they were pressed, *the friction was diminished by augmenting the rapidity;*[1] the friction, on the contrary, was increased when the surfaces were very large when compared with the force of pressure. When the wood was moved contrary to the direction of its fibres, the friction in every case remained the same. If wood be moved upon metals, the friction is greatly increased by an increase of velocity; and when metals move upon wood besmeared with tallow, the friction is still augmented by adding to the velocity. When metals move upon metals, the friction is always a constant quantity; but when heterogeneous substances are employed which are not bedaubed with tallow, the friction is so increased with the velocity, as to form an arithmetical progression when the velocities form a geometrical one.

7. *The friction of loaded cylinders rolling upon a horizontal plane, is in the direct ratio of their weights, and the inverse ratio of their diameters.*—In Coulomb's experiments, the friction of cylinders of guaiacum wood, which were two inches in diameter, and were loaded with 1000 pounds, was 18 pounds, or $\frac{1}{56}$ of the force of pressure. In cylinders of elm, the friction was greater by $\frac{2}{3}$, and was scarcely diminished by the interposition of tallow.

The following tables contain the most important results of Coulomb's researches, which we have arranged under three heads: 1. *Woods upon Woods;* 2. *Metals upon Metals;* and, 3. *Metals upon Woods.*

[1] The Abbé Bossut had anticipated this curious result, from theoretical considerations.

On the Nature and Diminution of Friction.

I.—*Friction of Woods upon Woods.*

1. *Friction of oak upon oak, when freshly greased with tallow at every experiment.*

Pressure.	Friction in Parts of the Pressure.	Pressure.	Co-efficient of Friction.
50 pounds	$\frac{1}{7{\cdot}7}$	850 pounds	$\frac{1}{23{\cdot}6}$
250 pounds	$\frac{1}{18{\cdot}5}$	1650 pounds	$\frac{1}{25{\cdot}8}$
450 pounds	$\frac{1}{21{\cdot}5}$	3250 pounds	$\frac{1}{27{\cdot}6}$.

The *increase* of friction produced by a *diminution* of *pressure* is here very remarkable. Coulomb ascribes it to the *cohesion* of the parts of the tallow, the influence of which increases as the pressure is diminished. He considers five pounds as a measure of this cohesion, and deduces $\frac{1}{28{\cdot}3}$ as the relation of the friction to the pressure when corrected for the cohesion of the tallow.

2. *Friction of oak upon oak, greased with tallow, and depending on the time of contact. The area of the rubbing surface was* 180 *square inches.*

Pressure.	Time of Contact.	Co-efficient of Friction.
47 pounds	0 minutes	$\frac{1}{7{\cdot}7}$
	4 minutes	$\frac{1}{5{\cdot}87}$
	2 hours	$\frac{1}{5{\cdot}25}$
1650 pounds	0 seconds	$\frac{1}{25{\cdot}8}$
	3 seconds	$\frac{1}{10{\cdot}3}$
	15 seconds	$\frac{1}{7{\cdot}9}$
	1 minute	$\frac{1}{5{\cdot}82}$
	4 minutes	$\frac{1}{5{\cdot}25}$
	2 hours	$\frac{1}{3{\cdot}65}$
	6 days	$\frac{1}{2{\cdot}65}$
3250 pounds	0 seconds	$\frac{1}{27{\cdot}1}$
	3 seconds	$\frac{1}{10{\cdot}16}$
	15 seconds	$\frac{1}{9{\cdot}16}$
	1 minute	$\frac{1}{7{\cdot}87}$
	4 minutes	$\frac{1}{5{\cdot}48}$
	1 hour	$\frac{1}{3{\cdot}7}$
	2 hours	$\frac{1}{3{\cdot}53}$
	Five days	$\frac{1}{2{\cdot}66}$
		$\frac{1}{2{\cdot}09}$.

The following results were obtained with still higher pressures, and with tallow that had been laid on and used for some time, without being renewed in the course of the experiments:—

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Pressure.	Time of Contact.	Co-efficient of Friction.
2310 pounds	0 minutes	$\frac{1}{12{\cdot}3}$
	2 minutes	$\frac{1}{5{\cdot}9}$
	1 hour	$\frac{1}{5{\cdot}12}$
	16 hours	$\frac{1}{4{\cdot}5}$
5810 pounds	0 minutes	$\frac{1}{11{\cdot}57}$
	2 minutes	$\frac{1}{7{\cdot}35}$
	4 minutes	$\frac{1}{6{\cdot}71}$
	9 minutes	$\frac{1}{6{\cdot}12}$
	26 minutes	$\frac{1}{5{\cdot}6}$
	1 hour	$\frac{1}{4{\cdot}9}$
	16 hours	$\frac{1}{3{\cdot}8}$.

3. *Friction of oak upon oak, in the direction of the fibres, and when the surfaces are in motion, and without grease.*

Pressure.	Co-efficient of Friction.
Surfaces one foot square. 25 pounds	$\frac{1}{5{\cdot}7}$
188 pounds	$\frac{1}{9{\cdot}4}$
291 pounds	$\frac{1}{9{\cdot}5}$
1788 pounds	$\frac{1}{9{\cdot}2}$
6588 pounds	$\frac{1}{10{\cdot}4}$
Surfaces reduced almost to lines. 47 pounds	$\frac{1}{10{\cdot}4}$
447 pounds	$\frac{1}{12{\cdot}4}$
847 pounds	$\frac{1}{14{\cdot}6}$.

When the velocities varied from nothing to four feet in four or five seconds, the results were not sensibly changed.

II.—*Friction of Metals upon Metals.*

1. *Friction of iron upon iron, and upon brass, after a certain time of rest.*

The rulers of iron used were four feet long and two inches wide, attached to the fixed plank of the apparatus. Other four rulers were employed, two of iron and two of brass, fifteen inches long and eighteen lines wide. The

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angles of the rulers were rounded, and the rubbing surfaces were forty-five square inches.

	Pressure.	Co-efficient of Friction.		Pressure.	Co-efficient of Friction.
Iron upon iron.....	53 pounds	$\frac{1}{3{\cdot}5}$	Iron upon brass...	52 pounds	$\frac{1}{4{\cdot}2}$
	453 pounds	$\frac{1}{3{\cdot}6}$		452 pounds	$\frac{1}{4{\cdot}1}$.

The friction is here independent of the extent of the rubbing surfaces, and Coulomb found that it did not vary with the velocities. In the case of iron upon brass, when the surfaces are extremely small, the friction varies from $\frac{1}{4{\cdot}1}$ to $\frac{1}{6{\cdot}1}$; but it does not reach this last ratio till the friction has been continued above an hour, when the iron and brass have taken their highest polish, and become free of scratches.

2. *Friction of iron upon brass when greased with tallow.*

	Pressure.	Time of Contact.	Co-efficient of Friction.
Brass upon iron.	50 pounds	0 minutes	$\frac{1}{8{\cdot}33}$
		4 minutes	$\frac{1}{7{\cdot}14}$
		30 minutes	$\frac{1}{7{\cdot}14}$
	450 pounds	0 minutes	$\frac{1}{10{\cdot}7}$
		4 minutes	$\frac{1}{9{\cdot}37}$
		2 hours	$\frac{1}{9{\cdot}37}$
	1650 pounds	0 minutes	$\frac{1}{11}$
		3 minutes	$\frac{1}{10{\cdot}4}$
		4 hours	$\frac{1}{9{\cdot}8}$
		4 days	$\frac{1}{9{\cdot}8}$.

The great degree of friction produced with the small pressure of fifty pounds, is owing to the cohesion of the tallow, which amounted to $1\frac{1}{2}$ pounds, which makes the friction $\frac{1}{11}$ at the shortest time of contact, and $\frac{1}{9{\cdot}5}$ when it had reached its maximum.

2. *Friction of iron upon iron, and upon brass, when highly polished.*

After the surfaces were polished as highly as possible, and greased with oil or tallow, they were attached to the sledge, and made to rest upon one another under a great pressure for half an hour, the grease being from time to time renewed, till it had penetrated the pores of the metal, and in this manner communicated to the rulers a degree of polish which they could not have received from any other method. The size of the rulers was the same as in section 1, and the areas in contact the same. The velocity of the sledge was below an inch in a second. The friction was at first uncertain, but it became more regular as the polish increased.

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	Pressure.	Co-efficient of Friction.
Iron upon iron...	53 lbs.	$\frac{1}{6{\cdot}2}$
	443 lbs.	$\frac{1}{10{\cdot}1}$
	1653 lbs.	$\frac{1}{10{\cdot}3}$
Iron upon brass..	53 lbs.	$\frac{1}{8}$
	443 lbs.	$\frac{1}{10{\cdot}7}$
	1653 lbs.	$\frac{1}{11}$
Iron upon brass when the grease was not renewed	53 lbs.	$\frac{1}{8}$
	443 lbs.	$\frac{1}{8{\cdot}1}$
	1653 lbs.	$\frac{1}{7{\cdot}9}$.

In one of these experiments, when the sledge moved *one foot in a second*, the friction of the sledge was under a pressure of 1652 pounds, *more than one third less* than when the velocity was insensible, or even *one inch in a second.*

III.—*Friction of Metals upon Wood.*

1. *Friction of iron upon oak, the surfaces not being greased.*

Pressure.	Time of Contact.	Co-efficient of Friction.
53 pounds	$\frac{1}{2}$ a second	$\frac{1}{10{\cdot}6}$
	30 seconds	$\frac{1}{10{\cdot}1}$
	60 seconds	$\frac{1}{8{\cdot}1}$
	1 hour	$\frac{1}{5{\cdot}89}$
	4 days	$\frac{1}{5{\cdot}3}$
1650 pounds	$\frac{1}{2}$ a second	$\frac{1}{13{\cdot}2}$
	10 seconds	$\frac{1}{12{\cdot}7}$
	80 seconds	$\frac{1}{11{\cdot}38}$
	4 hours	$\frac{1}{8{\cdot}25}$
	16 hours	$\frac{1}{5{\cdot}9}$
	4 days	$\frac{1}{4{\cdot}86}$.

In these experiments the friction does not obtain its maximum till after a long time.

2. *Friction of brass upon oak.*

The results were nearly the same as with iron upon oak. The friction, however, increased more slowly with the time, and at its maximum it was $\frac{1}{5{\cdot}5}$.

3. *Friction of iron upon oak, the surfaces not being greased.*

When the velocity was *insensible*, the results were,

	Pressure.	Co-efficient of Friction.
Iron upon oak	53 pounds	$\frac{1}{11{\cdot}8}$
	453 pounds	$\frac{1}{12{\cdot}9}$
	853 pounds	$\frac{1}{12{\cdot}7}$
	1653 pounds	$\frac{1}{13{\cdot}2}$.

When the velocity was *one foot* per second, the results were,

Iron upon oak	53 pounds	$\frac{1}{5{\cdot}9}$
	453 pounds	$\frac{1}{5{\cdot}8}$
	853 pounds	$\frac{1}{5{\cdot}5}$
	1653 pounds	$\frac{1}{6{\cdot}3}$.

Hence it follows, 1*st*, that the friction is nearly constant whatever be the pressure, the velocity being the same; 2*d*, that the friction increases greatly with the velocity; 3*d*, that the frictions increase in an arithmetical progression when the velocities increase in a geometrical one. Coulomb likewise found that when the pressure and velocity were the same, the friction was the same for large and small surfaces.

4. *Friction of iron and brass on oak, the surfaces being greased.*

Friction is greatly diminished when the metals rub upon wood greased with fatty bodies, and *small velocities* may be in this case produced with less force than in any other kind of friction.

When the velocities are greater, the friction increases rapidly with the velocity; as in the case already stated when dry metals rub upon wood. With small velocities the following results were obtained:

	Pressure.	Co-efficient of Friction.
Iron upon oak	1650 pounds	$\frac{1}{35{\cdot}1}$
Brass upon oak	1650 pounds	$\frac{1}{47{\cdot}1}$.

These results are highly important in practice; but the grease must not be allowed to acquire any consistency, otherwise the friction increases very perceptibly. It must therefore be removed, and renewed when necessary. In order to obtain an estimate of the influence of this thickening of the grease, Coulomb caused the sledge, when carrying the plates of brass, to move fifteen times over the fixed oaken plank, without removing or renewing the tallow. The consequence of this was, that the friction was triple of that which was necessary to give the sledge an insensible velocity when the tallow coating was new. The velocity of the sledge diminished, or the friction increased, at every trial; and at the fifteenth trial the *sledge ceased to move*. Hence it follows that the tallow actually increases the friction, or is injurious, when the surfaces move a long time without a renewal of the grease.

5. *Friction of iron upon oak greased, the surfaces being very small, and the friction across the grain of the wood.*

The surfaces were covered with tallow, and afterwards wiped, in order merely to leave them greasy.

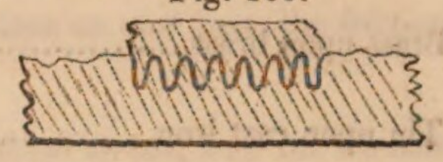
	Pressure.	Co-efficient of Friction.
Iron upon oak	47 pounds	$\frac{1}{13{\cdot}4}$
	447 pounds	$\frac{1}{14{\cdot}9}$
	1647 pounds	$\frac{1}{14{\cdot}3}$.

The results were nearly the same when the surfaces were well tallowed. The ratio of the friction to the pressure is constant, and not much influenced by the velocity. This case is analogous to the case of axles of iron turning upon wood.

From the preceding experiments, Coulomb has drawn the following curious inferences respecting the structure of the surfaces of woods and metals.

He supposes that the fibres of wood are as shown in fig. 109, which represents one surface lying upon another.

Fig. 109.



When the fibres are bent by the application of a force to the upper surface, but before the fibres are detached from one another, he supposes the two surfaces to be like fig. 110.

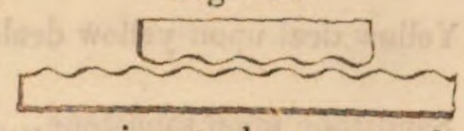
Fig. 110.

When the surfaces are detached, and the upper surface is in motion over the under one, he supposes the surface to be as in fig. 111.

Fig. 111.

He considers the surfaces of metals to be more smooth than those of wood, and to have the undulated structure shown in fig. 112.

Fig. 112.



A series of very valuable experiments have recently been made upon friction by Mr George Rennie,[1] under pressures of *thirty-six pounds to the square inch*, and within the limits of abrasion of the softest substance. The following table contains a general abstract of results collected from the different tables. The co-efficient of friction is contained in the first column, and the limiting angle of resistance[2] in the second. This angle has for its tangent the numbers in the first column, and is that angle at and beneath which the moving surface will not begin to slide.

Mr George Rennie's experiments on friction.

Tabular View of Mr Rennie's Experiments on Friction.

Names of the Substances.	Co-efficient of Friction.	Limiting Angle of Resistance.
Steel upon ice	$\frac{1}{69{\cdot}81}$	0° 49′
Ice upon ice	$\frac{1}{36{\cdot}00}$	1 35
Hard wood upon hard wood	$\frac{1}{7{\cdot}73}$	7 22

[1] Phil. Trans. 1829, p. 169.

[2] Professor Moseley's Mechanics applied to the Arts, p. 47. In Professor Moseley's table, there are some oversights near the beginning, which we have corrected here.

On the Nature and Diminution of Friction.

Names of the Substances.	Co-efficient of Friction.	Limiting Angle of Resistance.
Brass upon wrought iron	1/7·38	7° 43′
Brass upon cast iron	1/7·11	8 0
Brass upon steel	1/7·20	7 54
Soft steel upon soft steel	1/6·85	8 18
Cast iron upon steel	1/6·62	8 36
Wrought iron upon wrought iron	1/6·26	9 5
Cast iron upon cast iron	1/6·12	9 17
Hard brass upon cast iron	1/6·00	9 27
Cast iron upon wrought iron	1/5·87	9 40
Brass upon brass	1/5·70	9 57
Tin upon cast iron	1/5·59	10 8
Tin upon wrought iron	1/5·53	10 15
Soft steel upon wrought iron	1/5·28	10 53
Leather upon iron	1/4·00	14 21
Tin upon tin	1/3·78	14 49
Granite upon granite	1/3·30	16 52
Yellow deal upon yellow deal	1/2·88	19 9
Sandstone upon sandstone	1/2·75	19 59
Woollen cloth upon woollen cloth	1/2·30	23 30.

Mr Rennie has drawn the following conclusions from his experiments.

1. The laws which govern the retardation of bodies gliding over each other are as the nature of the bodies.

2. In fibrous substances, such as cloth, friction is increased by surface and time, and diminished by pressure and velocity.

3. In harder substances, such as woods, metals, and stones, and within the limits of abrasion, the friction is directly as the pressure, without regard to surface, time, or velocity.

4. With dissimilar substances, the friction will be determined by the limit of abrasion of the softer substance.

5. Friction is greatest with *soft*, and least with *hard*, substances.

6. The effect of unguents is as the nature of the unguents, without reference to the substances to which they are applied.

7. The very soft woods, stones, and metals, approximate to the laws which regulate the friction of fibrous substances.

In comparing his results with those of Coulomb, Mr Rennie found that the differences relate chiefly to time, and he conceives that the small pressures used by the French philosopher (varying from one pound to forty-five pounds per square inch) account for these differences.

On the Nature and Diminution of Friction.

The selection of substances used by Mr Rennie was made on the following grounds:

1. *Ice*, in reference to its resistance to sledges, skates, &c.
2. *Leather*, from its utility in the pistons of pumps.
3. *Stones*, in reference to their use in arches and buildings.
4. *Cloth*, from its remarkable properties of resistance in opposition to the law observed by solids.
5. *Woods* and *metals*, from their universal application to machinery, carriages, and railways.

Friction of leather upon iron.

Mr Rennie's experiments on leather are very interesting. When nine square inches of leather, *soaked in water*, moved over a plate of iron, seven pounds barely kept in motion fifty-six pounds after starting with the hand. After a contact of five minutes twenty-nine pounds were required to start it; twenty-eight pounds barely kept in motion sixty-four pounds after starting it; and after being one minute in contact it took forty-two pounds to start it.

Where a surface of four and half inches area (one and a half by three) was used, six and a half pounds barely kept in motion thirty-six pounds after starting it. After remaining five minutes it required twenty-one pounds to start it. Hence *the friction of hide leather soaked in water is greatly increased by time and weight*, a fact which explains the enormous friction evinced in the pistons of pumps when first put in motion.

When the hide leather moved *dry* over a surface of cast iron, the friction evinced from one fourth to nearly one sixth of the pressure, and was, *cæteris paribus*, diminished by a diminution of surface. The surfaces employed were two and a fourth, four and a half, six and three fourths, and nine square inches.

Friction of stones.

The following are the angles at which different stones commence gliding. On

Well-dressed stones	28°	to 36°	Rondelet.
	39	to 40	Perronet.
Granite voussoirs of the New London Bridge, well dressed, and without mortar	33	to 34	Rennie.
With fresh and finely ground mortar	25	to 26	ditto.
Sandstone voussoirs from Bramley, Fall, and Whitby	35	to 36	
With mortar	33	to 34	

According to Morisot, granite resists abrasion twelve times more than lias, while it possesses a repulsive power only three times greater. According to Boistard, the friction of hard calcareous stones is 0·78.

On the Friction of Axles.

In order to ascertain the friction experienced by the axles of machinery in motion, Coulomb used axles of iron moving in boxes of brass. The iron axis had a diameter of nineteen lines, and a play of one and three-fourth lines in the brass box. In order to give the rubbing surfaces the highest polish, the iron axis was made to work a considerable time in the brass box. The following is a brief abstract of the results which were obtained.

Pressure on Axis.	Kind of Greasing.	Co-efficient of Friction.
226 lbs.	No greasing	1/5·4
424 lbs.	Ditto	1/6·5
825 lbs.	Ditto	1/6·4

On the Nature and Diminution of Friction.

Pressure on Axis.	Kind of Greasing.	Co-efficient of Friction.
216 lbs.	Greased with tallow	1/12·3
420 lbs.	Ditto	1/11·6
827 lbs.	Ditto	1/11·5
117 lbs.	With cart-grease	1/6·7
218 lbs.	Ditto	1/8·4
320 lbs.	Ditto	1/8
422 lbs.	Ditto	1/8·5
831 lbs.	Ditto	1/8·3.

The cart grease of the preceding experiments was wiped off, the pores of the metal remaining unctuous,—

200 to 1200 lbs..... 1/7·9.

The surface of the metals was now fresh greased with olive oil,—

200 to 1200 lbs..... 1/7·5 to 1/7·9.

When the greasing had not been renewed for a long time, though the machine had been much used,—

200 to 1200 lbs..... 1/7·5.

From these experiments it appears that *tallow* was much more efficacious than *cart-grease* in diminishing the friction.

When the axles and the boxes or cheeks were made of different kinds of wood, the following results were obtained. The axes were three inches in diameter, and sometimes moveable and sometimes fixed (in both which cases the friction was the same, and the touching surfaces were carefully smoothed).

Nature of the Axis.	Nature of the Box.	Co-efficient of Friction.
Holm oak running in a box of.....	Lignum vitæ,	1/26·3
Ditto, the coating of tallow wiped off, and the surfaces being greasy.....	ditto,	1/16·7
Ditto, after being used several times without renewing the tallow.....	ditto,	1/16·7 to 1/12·5
Ditto, coated with tallow, and running in a box of.....	Elm,	1/33·3
Ditto, both axis and box wiped, the surfaces being greasy.....	ditto,	1/20
Box-wood coated with tallow, and running in a box of....	Lignum vitæ,	1/23
Ditto, both axis and box wiped, the surfaces being greasy.....	ditto,	1/14·3
Ditto, coated with tallow, and running in a box of.....	Elm,	1/28·6
Ditto, both axis and box wiped, and surfaces remaining greasy.....	ditto,	1/20
Axis of iron, coating of tallow wiped off, and the axle turned for some time	Lignum vitæ,	1/20.

On the Nature and Diminution of Friction.

In all these experiments, the friction was least when the surfaces were merely greasy, and not coated with tallow. Unless in the first instants of rest, the velocity did not seem to affect the friction.

Mr G. Rennie's experiments on the friction of axles.

A series of valuable experiments on the friction of axles, both *with* and *without* unguents, was made by Mr George Rennie. The weights with which he loaded the axle were generally about ten or eleven hundredweight, and in some cases he varied it down to one hundredweight.

Without unguents the friction of gun-metal on cast iron, when loaded with weights varying from one to ten hundredweight, varied from 1/7·65 to 1/4·70, and it was scarcely affected by length of time.

With yellow brass on cast iron the friction was greater, viz. 1/4·11.

With cast iron on cast iron the friction was 1/6.

With black lead and cast-iron on cast iron, the friction was diminished to 1/7·65.

With black lead and gun-metal on cast iron the friction was 1/7·24.

With black lead and yellow brass on cast iron the friction varied from 1/7·59 to 1/6·80, as the pressure increased from one to eleven hundredweight.

With oil, gun-metal on cast iron gave the friction 1/5·63.

With oil, yellow brass on cast iron gave the friction as follows:

Weight on Axle.	Co-efficient of Friction.	Weight on Axle.	Co-efficient of Friction.
½ cwt.....	1/37·33	4 cwt.....	1/18·28
1 cwt.....	1/32·00	5 cwt.....	1/19·14
2 cwt.....	1/32·00	10 cwt.....	1/5·78
3 cwt.....	1/20·36	11 cwt.....	1/6·13

This great increase of friction with the weight Mr Rennie ascribes to the oil "being less fluid and sensible in the one case, and more capable of preventing the contact of metals in the other."

With oil, cast iron on cast iron gave the friction 1/8·67

With hog's lard, cast iron on cast iron gave the friction 1/9·55.

With hog's lard, yellow brass on cast iron, the results were as follows:

Weight.	Co-efficient of Friction.	Weight.	Co-efficient of Friction.
½ cwt.....	1/34·46	4 cwt.....	1/10·41
1 cwt.....	1/36·57	5 cwt.....	1/11·78
2 cwt.....	1/29·86	10 cwt.....	1/9·29
3 cwt.....	1/14·60		

On the Nature and Diminution of Friction.

With hog's lard, gun-metal on cast iron, the friction was $\frac{1}{8{\cdot}39}$ with a pressure of ten hundredweight.

With anti-attrition composition, yellow brass on cast iron, the results were as follows:

Weight.	Co-efficient of Friction.	Weight.	Co-efficient of Friction.
1 cwt.	$\frac{1}{14{\cdot}93}$	5 cwt.	$\frac{1}{38{\cdot}62}$
2 cwt.	$\frac{1}{24{\cdot}88}$	10^1 cwt.	$\frac{1}{5{\cdot}89}$
3 cwt.	$\frac{1}{32{\cdot}00}$	10^2 cwt.	$\frac{1}{47{\cdot}65}$
4 cwt.	$\frac{1}{35{\cdot}84}$	10 cwt.	$\frac{1}{56{\cdot}00}$

With tallow, yellow brass on cast iron, the friction varied from $\frac{1}{36{\cdot}57}$ to $\frac{1}{40{\cdot}72}$, as the pressure varied from 1 to 5 hundredweight.

With soft soap, yellow brass on cast iron, the friction varied from $\frac{1}{26{\cdot}35}$ to $\frac{1}{37{\cdot}96}$, as the pressure varied from $\frac{1}{2}$ to 5 hundredweight.

With soft soap and black lead, yellow brass on cast iron, the friction varied from $\frac{1}{10{\cdot}18}$ to $\frac{1}{23{\cdot}82}$, as the pressure varied from $\frac{1}{2}$ to 5 hundredweight.

From these various results, which we have abridged as much as possible, Mr Rennie concludes "that the diminution of friction by unguents varies as the insistent weights and nature of the unguents: the lighter the weight, the finer and more fluid should be the unguent, and *vice versa*."

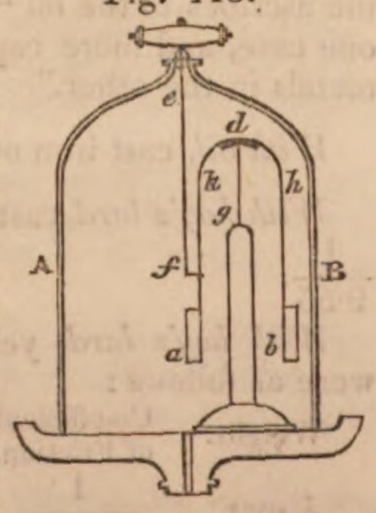
On the Friction of Pivots.

In the construction of clocks and watches, and all delicate pieces of machinery, but particularly in the formation of compasses, the proper form of pivots, as well as the material of which they are made, and in which they move, are subjects of the greatest importance.

All that we know on this subject is due to the celebrated Coulomb, who made two different sets of experiments on the friction of pivots. The last was made with most accuracy, and *in vacuo*, to get rid of the effects of the air's resistance.

The apparatus used by Coulomb is shown in the annexed figure, where *akhb* is a brass wire fork, fixed at *d* to a concave lens of glass, whose radius is about two or three lines. Two metallic plates *a*, *b* are fixed to the lower ends of the bent wire, and the whole moves upon a pivot beneath *d*, at the upper end of the needle *gd*, which was made of tempered steel, and fixed into the cylindrical stand. A rotatory motion is given to the fork by a hooked rod *ef*, and the whole is enclosed in an air-tight glass receiver AB, in which a vacuum is made in the usual manner by an air-pump. Coulomb found that when *ab* was two inches, the time of the fork's revolution was seven or eight seconds, and the weight of *a* and *b* about five or six gros (a gros is about the eighth part of an ounce). It is unnecessary to perform the experiments *in vacuo*, though it is proper to protect the apparatus from currents of air, by placing it under a receiver.

Fig. 113.



On the Nature and Diminution of Friction.

In order to compare the experimental results, Coulomb investigated the following formula:[3]

$$A = \frac{b^2}{X} \times \int \frac{\mu r^2}{a};$$

in which A is the momentum of friction, *b* the primitive velocity, X the space described from the beginning to the end of the motion, $\int \frac{\mu r^2}{a}$ the sum of each molecule μ multiplied into the square of its distance *r* from the axis of motion, and divided by the distance *a* from the axis of motion of a point whose velocity is *b*. When the same receiver is used, $\int \frac{\mu r^2}{a}$ is a constant quantity.

With a different apparatus Coulomb made the following preliminary experiments. He took a glass receiver, four inches wide, five inches high, and five ounces in weight, and having caused this to revolve upon a pivot, he observed the time employed in making the *four* or *five* first turns, from a mean of which he obtained the primitive velocity *b*, and he then counted the number of revolutions performed by the revolving receiver till it stopped. Having found that the resistance of the air bore no sensible proportion to that of friction, the preceding results enabled him to calculate the friction by which the receiver was brought to rest. The following were the results:—

Time of performing One Revolution.	Number of Revolutions performed before the Apparatus stopped.	Values of $\frac{b^2}{X}$.
4 seconds	34·1	$\frac{1}{547}$
6·25 seconds	14·1	$\frac{1}{550}$
11 seconds	4·6	$\frac{1}{557}$

Now, as the *second* term of the above expression for the momentum of friction is constant, and as the value of $\frac{b^2}{X}$, the first term, appears to be constant in the preceding experiments, the average of which is $\frac{1}{551}$, A or the momentum of friction is also constant; and hence Coulomb drew the conclusion, that *the friction of pivots is independent of the velocity*, and must therefore depend on the pressure.

In order to determine the friction of pivots when they supported planes of different materials, Coulomb used the apparatus represented above. The fork *akhb* was nine inches long, the distance of the branches *akhb* twenty-four lines, the curve *cdh* was a semicircle of about three inches long, and the branches *ak*, *hb* three inches long. The pieces of metal *a*, *b*, and the plane *d*, were attached to the wire by wax. At *g*, the top of the cylindrical support, was fixed a small needle of tempered steel, whose point could be made more or less sharp or obtuse, as the nature of the planes and the magnitude of the pressure required. The angle of the point at *g* was, in the following experiments, eighteen or twenty degrees, the weight of *a* and *b* was a quarter of an ounce, and that of the fork about one fifth of an ounce.

[1] After remaining 41 hours in a state of rest with ten hundredweight.

[2] Fresh composition having been applied.

[3] See *Mém. Acad. Par.* 1790, p. 451, 452.

On the Nature and Diminution of Friction.

Nature of the Planes.	Time of performing one Revolution.	Number of Revolutions performed before the Apparatus stopped.	Values of $\frac{b^2}{X}$.	Momentum of Friction.
Steel, plane at *d*	17 seconds	1·75	$\frac{1}{510}$	2·257
Tempered and polished	8 seconds	7·25	$\frac{1}{464}$	
Glass, plane	8·75 seconds	7·5	$\frac{1}{570}$	1·777
Highly polished	4·25 seconds	2·9	$\frac{1}{589}$	
Rock crystal, plane	13 seconds	4·62	$\frac{1}{781}$	1·313
Highly polished	14·5 seconds	3·75	$\frac{1}{787}$	
Agate, plane	9 seconds	10·5	$\frac{1}{851}$	1·214
Highly polished	15 seconds	3·5	$\frac{1}{844}$	
Garnet, plane	12 seconds	7	$\frac{1}{1008}$	1·000
Highly polished	23 seconds	2	$\frac{1}{1050}$	

From these experiments, it is evident that *garnet* is the best material for the cups of pivots, agate the next, rock crystal the next, glass the next, and steel the worst.

Coulomb next proceeded to determine the effects produced by giving different angles to the pivots of the needle, the other circumstances remaining as before.

Nature of the Planes.	Values of $\frac{b^2}{X}$. Angles of Pivots, 45°.	15°.	6° or 7°.
Steel	$\frac{1}{2000}$	—	$\frac{1}{230}$
Glass	$\frac{1}{1400}$	—	$\frac{1}{450}$
Agate	$\frac{1}{2100}$	$\frac{1}{1200}$	$\frac{1}{800}$
Garnet	$\frac{1}{2500}$	...	...

Hence it appears, that in all the planes except the steel one, *the friction increases with the acuteness of the pivot*, and follows nearly the same ratio. In agate and steel, however, the friction, at an acuteness of 45°, is nearly equal, whereas, when the angle of the pivot is reduced to 6° or 7°, the friction of the steel is nearly four times as great as that of the agate. Coulomb ascribes this to an infinite number of minute pores in steel, even when it has the highest polish; the sharp point of the pivot working in these irregular openings.

Coulomb found, that when the body weighs about three fourths of an ounce, the best angle is from 30° to 45°. With less weights, the angle of the pivot may be even reduced to 10° or 12° when the steel is good, provided the weight is not more than 100 grains.

In order to determine the relation of the friction to the pressure, Coulomb repeated the experiment by varying the weights *a* and *b*. He took a pivot of the best tempered steel, wrought to the first degree of steel temper. He made its angle about 45°, and made it support in succession planes of highly polished *glass* and *garnet*. The distance *ab* was twenty-four lines, and the weight of the fork $1\frac{1}{3}$ gros, or about one sixth of an ounce.

With a Plane of Polished Glass.

Pressure on the Pivot, in Ounces.	Time of performing One Revolution.	Number of Revolutions performed before the Apparatus stopped.	Values of $\frac{b^2}{X}$.
0·41	24 seconds	2	$\frac{1}{1152}$
	14 seconds	5·75	$\frac{1}{1127}$
	10 seconds	11·75	$\frac{1}{1173}$
2·08	9 seconds	10·75	$\frac{1}{830}$
	13 seconds	4·25	$\frac{1}{802}$

With a Plane of Garnet.

0·67	$\frac{1}{2400}$
2·08	$\frac{1}{1550}$

Hence it may be shown, that the momentum of friction is proportional to the $\frac{4}{3}$d power of the pressure. When the pressure was very considerable, and the pivot shaped to any angle, the friction varied nearly as the pressure. These results were deduced from the experiments with the glass plane, as the friction was greater and the results more regular with it than with either garnet or agate.

Coulomb found the cups made by the best workmen very irregular in their curvature, and producing a friction three or even four times greater than that of well-polished planes of the same substance. With such cups the angles of the pivots should be diminished.

On the Friction of Machines.

In the year 1786, and at subsequent periods, the late Mr John Rennie made several experiments on the friction and resistance of heavy machinery. He found that an augmentation of resistance took place with the quantity of machinery put in motion; in one instance in the ratio of one to five, when from one fifth to one tenth of the power expended was absorbed; an anomaly which Mr George Rennie ascribes to the irregularity of the movement, and to the difficulty of producing simultaneous actions in com-

On the Nature and Diminution of Friction.

plicated machinery. The resistance in these experiments was likewise increased by reversing the direction of motion. The velocities not exceeding 120 feet a minute, appeared to have had no influence.

The following experiments were made by Mr George Rennie:

1. *Twenty-one cwt.* was suspended at each extremity of a chain passing over two cast-iron sheaves two feet in diameter, with wrought-iron axles working in brass bearings oiled, and twelve feet ten inches apart. It was disturbed by three cwt. or $\frac{1}{14}$th of the total weight. Another double-purchased crane gave one ninth.

2. A weight of 7057 lbs. suspended to a double-purchased crane indicated $\frac{1}{7{\cdot}62}$ for the friction. Another similar one indicated one ninth. In one of the corn-mills at Deptford, it required one tenth of the weight of the mass to overcome the inertia and friction of the bearings and tangential surfaces. The pressures in this case varied from twenty-eight lbs. to eight cwt. per inch, and the velocities of the surfaces from 50 to 120 feet per minute.

Mr Rennie remarks, that it has been usual to deduct one fourth of the power expended for friction; but though this may hold in machines newly set in motion, he conceives that the proportion is much less when the bearings are properly proportioned to the weights of the parts, and their surfaces kept from contact by unguents.

Method of diminishing the effects of friction.

Having thus considered the nature and effects of friction, we shall now attend to the method of lessening the resistance which it opposes to the motion of machines. The most efficacious mode of accomplishing this, is to convert that species of friction which arises from one body being dragged over another, into that which is occasioned by one body rolling upon another. As this will always diminish the resistance, it may be easily effected by applying wheels or rollers to the sockets or bushes which sustain the gudgeons of large wheels and the axles of wheel-carriages.

Friction-wheels.

Casatus seems to have been the first who recommended this apparatus. It was afterwards mentioned by Sturmius and Wolfius, but was not used in practice till Sully applied it to clocks in the year 1716, and Mondran to cranes in 1725. Notwithstanding these solitary attempts to introduce friction-wheels, they seem to have attracted little notice, till the celebrated Euler examined and explained, with his usual accuracy, their nature and advantages. The diameter of the gudgeons and pivots should be made as small as the weight of the wheel and the impelling force will permit. The gudgeons should rest upon wheels as large as circumstances will allow, having their axes as near each other as possible, but no thicker than what is absolutely necessary to sustain the superincumbent weight. When these precautions are properly attended to, the resistance which arises from the friction of the gudgeon, &c. will be extremely trifling.[1]

Friction may be diminished by a judicious application of the impelling power.

The effects of friction may likewise in some measure be removed by a judicious application of the impelling power, and by proportioning the size of the friction-wheels to the pressure which they severally sustain. If we suppose, for example, that the weight of a wheel, whose iron gudgeons move in bushes of brass, is 100 pounds, then the friction arising from both its gudgeons will be equivalent to 25 pounds. If we suppose also that a force equal to 40 pounds is employed to impel the wheel, and acts in the direction of gravity, as in the cases of overshot-wheels, the pressure of the gudgeons upon their supports will then be 140 pounds and the friction 35 pounds. But if the force of 40 pounds could be applied in such a manner as to act in direct opposition to the wheel's weight, the pressure of the gudgeons upon their supports would be 100 — 40, or 60 pounds, and the friction only 15 pounds. It is impossible, indeed, to make the moving force act in direct opposition to the gravity of the wheel in the case of water-mills, and it is often impracticable for the engineer to apply the impelling power but in a given way; but there are many cases in which the moving force may be so exerted as at least not to increase the friction which arises from the wheel's weight.

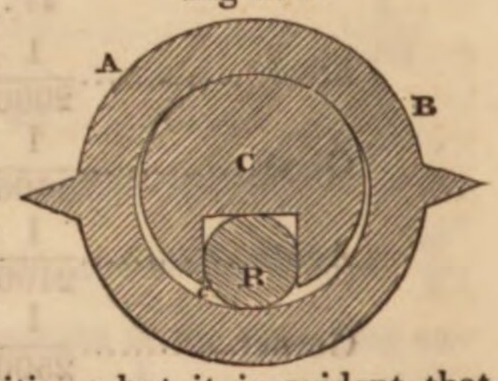
On the Nature and Diminution of Friction.

When the moving force is not exerted in a perpendicular direction, but obliquely, as in undershot-wheels, the gudgeon will press with greater force on one part of the socket than on any other part. This point will evidently be on the side of the bush opposite to that where the power is applied; and its distance from the lowest point of the socket, which is supposed circular and concentric with the gudgeon, being called x, we shall have tan. $x = \frac{H}{V}$, that is, the tangent of the arch contained between the point of greatest pressure and the lowest point of the bush, is equal to the sum of all the horizontal forces divided by the sum of all the vertical forces and the weight of the wheel, H representing the former, and V the latter quantities. The point of greatest pressure being thus determined, the gudgeon must be supported at that part by the largest friction-wheel, in order to equalize the friction upon their axles.

The application of these general principles to particular cases is so simple as not to require any illustration. To aid the conceptions, however, of the practical mechanic, we may mention two cases in which friction-wheels have been successfully employed.

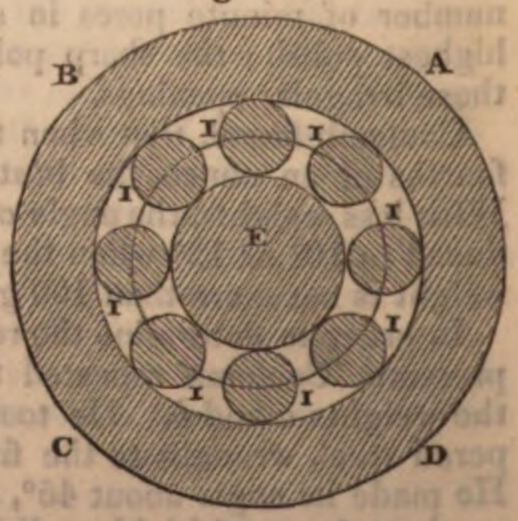
Mr Gottlieb, the constructor of a new crane, has received a patent for what he calls an anti-attrition axle-tree, the beneficial effects of which he has ascertained by a variety of trials. It consists of a steel roller R, about four or six inches long, which turns within a groove cut in the inferior part of the axle-tree C, which runs in the nave AB of the wheel. When the wheel-carriages are at rest, Mr Gottlieb has given the friction-wheel its proper position; but it is evident that the point of greatest pressure will change when they are put in motion, and will be nearer the front of the carriage. This point, however, will vary with the weight of the load; but it is sufficiently obvious that the friction-roller should be at a little distance from the lowest point of the axle-tree.

Fig 114.



Mr Gamett of Bristol has applied friction-rollers in a different manner, which does not, like the preceding method, weaken the axle-tree. Instead of fixing them in the iron part of the axle, he leaves a space between the nave and the axis, to be filled with equal rollers almost touching each other. A section of this apparatus is represented in fig. 115, where ABCD is the metallic ring inserted in the nave of the wheel. The

Fig. 115.



[1] An example of the application of friction-wheels is to be found in Atwood's machine, described in a subsequent part of this Article.

On the Nature and Diminution of Friction.

axle-tree is represented at E, placed between the friction-rollers I, I, I, made of metal, and having their axes inserted into a circle of brass, which passes through their centres. The circles are riveted together by means of bolts passing between the rollers, in order to keep them separate and parallel.

As it appears from the experiments of Coulomb that the least friction is generated when polished iron moves upon brass, the gudgeons and pivots of wheels, and the axles of friction-rollers, should all be made of polished iron; and the bushes in which these gudgeons move, and the friction-wheels, should be formed of polished brass.

Friction diminished by unguents.

When every mechanical contrivance has been adopted for diminishing the obstruction which arises from the attrition of the communicating parts, it may be still farther removed by the judicious application of unguents. The most proper for this purpose are swine's grease and tallow when the surfaces are made of wood, and oil when they are of metal. When the force with which the surfaces are pressed together is very great, tallow will diminish the friction more than swine's grease. When the wooden surfaces are very small, unguents will lessen their friction a little; but it will be greatly diminished if wood moves upon metal greased with tallow. If the velocities, however, are increased, or the unguent not often enough renewed, in both these cases, but particularly in the last, the unguent will be more injurious than useful. The best mode of applying it is to cover the rubbing surfaces with as thin a stratum as possible, for the friction will then be a constant quantity, and will not be increased by an augmentation of velocity.

In small works of wood, the interposition of the powder of black lead has been found very useful in relieving the motion. The ropes of pulleys should be rubbed with tallow, and whenever the screw is used, the square threads should be preferred.[1]

A very important unguent for diminishing the friction of machinery was accidentally discovered at Lowell in North America. The substance is *steatite* or *soapstone*, pulverised and mixed with oil, tallow, or tar, according to the use to which it is to be applied. It has been used most successfully in all kinds of machinery, and it is said to be equally applicable to carriage-wheels. The following fact, stated by Mr Moody, the superintendent of the tar-works near Boston, will show the value of steatite as an unguent. A horizontal balance-wheel of 14 tons runs on a step 5 inches in diameter, and revolves from 75 to 125 times in a minute. This wheel is connected with the rolling machine, and though 100 tons of iron are rolled in this machine in a minute, yet the balance-wheel has sometimes been used from *three to five weeks* without inconvenience before the soapstone has been renewed. When machinery is begun to be heated, its application is said to succeed when all other unguents fail.[2] In the case of carriage-wheels being set on fire by friction, the application of cow's dung is particularly effectual. A more recently-discovered unguent is mentioned in our chapter on wheel-carriages.

On the rigidity of ropes.

When ropes pass over cylinders or pulleys, a considerable force is necessary to bend them into the form of the circumference round which they are coiled. The force which is necessary to overcome this resistance is called the *stiffness* or *rigidity* of the ropes. This important subject was first examined by Amontons,[3] who contrived an ingenious apparatus for ascertaining the rigidity of ropes. His experiments were repeated, and confirmed in part, by Desaguliers[4] and others, but particularly by M. Coulomb, who has investigated the subject with more care and success than any of his predecessors. His experiments were made both with the apparatus of Amontons and with one of his own invention; and as there was no great discrepancy in the results, he was authorized to place more confidence in his experiments. The limits of this article will not permit us to give an account of the manner in which the experiments were conducted, or even to give a detailed view of the various conclusions which were obtained. We can only present the reader with some of those leading results which may be useful in the construction of machinery.

On the Rigidity of Ropes.

Results of Coulomb's experiments.

1. The rigidity of ropes increases, the more that the fibres of which they are composed are twisted.

2. The rigidity of ropes increases in the duplicate ratio of their diameters. According to Amontons and Desaguliers, the rigidity increases in the simple ratio of the diameters of the ropes; but this probably arose from the flexibility of the ropes which they employed; for Desaguliers remarks, that when he used a rope whose diameter was half an inch, its rigidity was increased in a greater proportion; so that it is probable that if they had employed ropes from two to four inches in diameter, like those used by Coulomb, they would have obtained similar results. (See No. 5.)

3. The rigidity of ropes is in the simple and direct ratio of their tension.

4. The rigidity of ropes is in the inverse ratio of the diameters of the cylinders round which they are coiled.

5. In general, the rigidity of ropes is directly as their tensions and the squares of their diameters, and inversely as the diameters of the cylinders round which they are wound.

6. The rigidity of ropes increases so little with the velocity of the machine, that it need not be taken into the account when computing the effects of machines.

7. The rigidity of small ropes is diminished when penetrated with moisture; but when the ropes are thick, their rigidity is increased.

8. The rigidity of ropes is increased and their strength diminished when they are covered with pitch; but when ropes of this kind are alternately immersed in the sea and exposed to the air, they last longer than when they are not pitched. This increase of rigidity, however, is not so perceptible in small ropes as in those which are pretty thick.

9. The rigidity of ropes covered with pitch is a sixth part greater during frost than in the middle of summer, but this increase of rigidity does not follow the ratio of their tensions.

10. The resistance to be overcome in bending a rope over a pulley or cylinder may be represented by a formula composed of two terms. The first term $\frac{aDn}{r}$ is a constant quantity independent of the tension, a being a constant quantity determined by experiment, Dn a power of the diameter D of the rope, and r the radius of the pulley or cylinder round which the rope is coiled. The second term of the formula is $T \times \frac{bDn}{r}$, where T is the tension of the rope, b a constant quantity, and Dn and r the same as before. Hence the complete formula is

$$\frac{aDn}{r} + T \times \frac{bDn}{r}, \text{ or } \frac{Dn}{r} \times a + Tb.$$

The exponent n of the quantity D diminishes with the flexibility of the rope, but is generally equal to 1·7 or 1·8; or, as in No. 2, the rigidity is nearly in the duplicate ratio of the diameter of the rope. When the cord is much used, its flexibility is increased, and n becomes equal to 1·5 or 1·4.

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[1] Appendix to Ferguson's Lectures, vol. ii.
[2] Professor Silliman's Journal, No. 27, p. 192.
[3] *Mém. Acad.* 1699, p. 217.
[4] Course of Nat. Phil. vol. i. p. 243.

On Fly-Wheels.

CHAP. IV.—ON THE NATURE AND ADVANTAGES OF FLY-WHEELS.

Advantages of fly-wheels,

A fly, in mechanics, is a heavy wheel or cylinder, which moves rapidly on its axis, and is applied to machines for the purpose of rendering uniform a desultory or reciprocating motion, arising either from the nature of the machinery, from an inequality in the resistance to be overcome, or from an irregular application of the impelling power. When the first mover is inanimate, as wind, water, and steam, an inequality of force obviously arises from a variation in the velocity of the wind, from an increase or decrease of water occasioned by sudden rains, or from an augmentation or diminution of the steam in the boiler, produced by a variation of heat in the furnace; and accordingly various methods have been adopted for regulating the action of these variable powers. The same inequality of force obtains when machines are moved by horses or men. Every animal exerts its greatest strength when first set to work. After pulling for some time, its strength will be impaired; and when the resistance is great, it will take frequent though short relaxations, and then commence its labour with renovated vigour. These intervals of rest and vigorous exertion must always produce a variation in the velocity of the machine, which ought particularly to be avoided, as being detrimental to the communicating parts as well as the performance of the machine, and injurious to the animal which is employed to drive it. But if a fly, consisting either of cross bars or a massy circular rim, be connected with the machinery, all these inconveniences will be removed. As every fly-wheel must revolve with great rapidity, the momentum of its circumference must be very considerable, and will consequently resist every attempt either to accelerate or retard its motion. When the machine therefore has been put in motion, the fly-wheel will be whirling with an uniform celerity, and with a force capable of continuing that celerity when there is any relaxation in the impelling power. After a short rest the animal renews his efforts; but the machine is now moving with its former velocity, and these fresh efforts will have a tendency to increase that velocity. The fly, however, now acts as a resisting power, receives the greatest part of the superfluous motion, and causes the machinery to preserve its original celerity. In this way the fly secures to the engine an uniform motion, whether the animal takes occasional relaxations or exerts his force with redoubled ardour.

as regulators of machinery,

We have already observed that a desultory or variable motion frequently arises from the inequality of the resistance, or work to be performed. This is particularly manifest in thrashing mills on a small scale, which are driven by water. When the corn is laid unequally on the feeding board, so that too much is taken in by the fluted rollers, this increase of resistance instantly affects the machinery, and communicates a desultory or irregular motion even to the water-wheel or first mover. This variation in the velocity of the impelling power may be distinctly perceived by the ear in a calm evening when the machine is at work. The best method of correcting these irregularities is to employ a fly-wheel, which will regulate the motion of the machine when the resistance is either augmented or diminished. In machines built upon a large scale there is no necessity for the interposition of a fly, as the *inertia* of the machinery supplies its place, and resists every change of motion that may be generated by an unequal admission of the corn.

A variation in the velocity of engines arises also from the nature of the machinery. Let us suppose that a weight of 1000 pounds is to be raised from the bottom of a well 50 feet, by means of a bucket attached to an iron chain which winds round a barrel or cylinder, and that every foot length of this chain weighs two pounds. It is evident that the resistance to be overcome in the first moment is 1000 pounds added to 50 pounds the weight of this chain, and that this resistance diminishes gradually as the chain coils round the cylinder, till it is only 1000 pounds when the chain is completely wound up. The resistance therefore decreases from 1050 to 1000 pounds; and if the impelling power is inanimate, the velocity of the bucket will gradually increase; but if an animal be employed, it will generally proportion its action to the resisting load, and must therefore pull with a greater or less force according as the bucket is near the bottom or top of the well. In this case, however, the assistance of a fly may be dispensed with, because the resistance diminishes uniformly, and may be rendered constant by making the barrel conical, so that the chain may wind upon the part nearest the vertex at the commencement of the motion, the diameter of the barrel gradually increasing as the weight diminishes. In this way the variable resistance will be equalized much better than by the application of a fly-wheel, for the fly, having no motion of its own, must necessarily waste the impelling power.

On Fly-Wheels.

Having thus pointed out the chief causes of variation in the velocity of machines, and the method of rendering it uniform by the intervention of fly-wheels, the utility, and in some instances the necessity, of this piece of mechanism, may be more obviously illustrated by showing the propriety of their application in particular cases.

When machinery is driven by a single-stroke steam-engine, there is such an inequality in the impelling power, that for two or three seconds it does not act at all. During this interval of inactivity the machinery would necessarily stop, were it not impelled by a massy fly-wheel of a great diameter, revolving with rapidity, till the moving power again resumes its energy.

If the moving power be a man acting with a handle or winch, it is subject to great inequalities. The greatest force is exerted when the man pulls the handle upwards from the height of his knee, and he acts with the least force when the handle, being in a vertical position, is thrust from him in a horizontal direction. The force is again increased when the handle is pushed downwards by the man's weight, and it is diminished when the handle, being at its lowest point, is pulled towards him horizontally. But when a fly is properly connected with the machinery, these irregular exertions are equalized, the velocity becomes uniform, and the load is raised with an equable and steady motion.

In many cases, where the impelling force is alternately augmented and diminished, the performance of the machine may be increased by rendering the resistance unequal, and accommodating it to the inequalities of the moving power. Dr Robison observes, that "there are some beautiful specimens of this kind of adjustment in the mechanism of animal bodies."

as accumulators of power.

Besides the utility of fly-wheels as regulators of machinery, they have been employed for accumulating or collecting power. If motion is communicated to a fly-wheel by means of a small force, and if this force is continued till the wheel has acquired a great velocity, such a quantity of motion will be accumulated in its circumference, as to overcome resistances, and produce effects which could never have been accomplished by the original force. So great is this accumulation of power, that a force equivalent to twenty pounds applied for the space of thirty-seven seconds to the circumference of a cylinder twenty feet diameter, which weighs 4713 pounds, would, at the distance of one foot from the centre, give an impulse to a musket-ball equal to what it receives from a full charge of gunpowder. In the space of six minutes and ten seconds, the same effect would be produced if the cylinder were driven by a

On Fly-Wheels.

man who constantly exerted a force of twenty pounds at a winch one foot long.[1]

This accumulation of power is finely exemplified in the *sling*. When the thong which contains the stone is swung round the head of the slinger, the force of the hand is continually accumulating in the revolving stone, till it is discharged with a degree of rapidity which it could never have received from the force of the hand alone. When a stone is projected from the hand itself, there is even then a certain degree of force accumulated, though the stone only moves through the arch of a circle. If we fix the stone in an opening at the extremity of a piece of wood two feet long, and discharge it in the usual way, there will be more force accumulated than with the hand alone, for the stone describes a larger arch in the same time, and must therefore be projected with greater force.

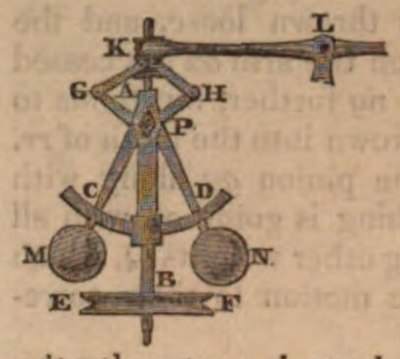
When coins or medals are struck, a very considerable accumulation of power is necessary, and this is effected by means of a fly. The force is first accumulated in weights fixed on the rim of the fly. This force is communicated to two levers, by which it is farther condensed; and from these levers it is transmitted to a screw, by which it suffers a second condensation. The stamp is then impressed on the coin or medal by means of this force, which was first accumulated by the fly, and afterwards augmented by the intervention of two mechanical powers. Hence it follows, that if the fly-wheel, thus loaded with accumulated power, should be detached from the steam-engine or the first mover, whose power it regulates and accumulates, it will go on for some time to do the work of the machine after the prime mover has ceased to act. This effect is finely illustrated by a fact stated by Mr Babbage:[2] "The powerful effect," says he, "of a large fly-wheel, when its force can be concentrated in a point, was curiously illustrated at one of the largest of our manufactories. The proprietor was showing to a friend the method of punching holes in iron plates for the boilers of steam-engines. He held in his hand a piece of sheet iron three eighths of an inch thick, which he placed under the punch. Observing, after several holes had been made, that the punch made its perforations more and more slowly, he called to the engine-man to know what made the engine work so sluggishly, when it was found that the fly-wheel and punching apparatus had been detached from the steam engine just at the commencement of the experiment."

Notwithstanding the great advantage of fly-wheels, both as regulators of machines and collectors of power, their utility wholly depends upon the position which is assigned them relative to the impelled and working points of the engine. For this purpose no particular rules can be laid down, as their position depends altogether on the nature of the machinery. We may observe, however, in general, that when fly-wheels are employed to regulate machinery, they should be near the impelling power; and when used to accumulate force in the working point, they should not be far distant from it. In hand-mills for grinding corn the fly is for the most part very injudiciously fixed on the axis to which the winch is attached, whereas it should always be fastened to the upper millstone, so as to revolve with the same rapidity. In the first position, indeed, it must equalize the varying efforts of the power which moves the winch; but when it is attached to the turning millstone, it not only does this, but contributes very effectually to the grinding of the corn.

Description of the conical pendulum.

A new kind of fly, called a conical pendulum, has been ingeniously employed by Mr Watt for procuring a determinate velocity at the working point of his steam-engine. It is represented in fig. 116, where AB is a vertical axis moving upon pivots, and driven by means of a rope passing from the axis of the large fly over the sheaf EF. The large balls M, N are fixed to the rods NG, MH, which have an angular motion round P, and are connected by joints at G and H, with the rods GK, HK attached to the extremity of the lever KL, whose centre of motion is L, and whose other extremity is connected with the cock which admits the steam into the cylinder. The frame CD prevents the balls from receding too far from the axis, or from approaching too near it. Now when this conical pendulum is put in motion, the centrifugal force of the balls M, N makes them recede from the axis AB. In consequence of this recession, the points G, H, K are depressed, and the other extremity of the lever is raised, and the cock admits a certain quantity of steam into the cylinder. When the velocity of the fly is by any means increased, the balls recede still farther from the axis, the extremity of the lever is raised higher, and the cock closes a little and diminishes the supply of steam. From this diminution in the impelling power, the velocity of the fly and the conical pendulum decreases, and the balls resume their former position. In this way, when there is any increase or diminution in the velocity of the fly, the corresponding increase or diminution in the centrifugal force of the balls raises or depresses the arm of the lever, admits a greater or a less quantity of steam into the cylinder, and restores to the engine its former velocity.

Fig. 116.



In like manner, four iron balls have been applied to the axis of a millstone to regulate its motion.[3]

Prony's condenser of forces.

Among the contrivances analogous to fly-wheels, the most useful and ingenious is that of Baron Prony, to which he has given the name of the *Condenser of Forces*. The problem which Prony proposes to solve is, to transmit to any machine whose construction is determinate the action of the first mover, and to fulfil the following conditions:

1. To vary speedily and easily the resistance which the first mover is intended to overcome.
2. To preserve the resistance constant till it is proper to increase or diminish it.
3. To preserve the velocity of the machine constant under the most sudden variations of the first mover.

The section and plan of a machine for applying his invention to a wind-mill is shown in figs. 6 and 7 of Plate CCCLI. The wind-mill sails, which are not shown in the figures, are supposed to give motion to the vertical arbor O, which carries a quadrangular frame *eeee*, at each angle of which is fixed a curved wire of iron or steel *bd*. Round the main arbor O are situated several vertical arbors *a*, *a*, *a*, *a* (eight being shown in fig. 2), each carrying a curved piece of iron or steel *af*, so constructed that when the arbor O revolves, all the other arbors *a* will revolve also by the action of the arms *bd*, &c. upon *af*, &c. the succeeding curve *bd* beginning to act upon the corresponding one *af*, when the preceding *bd* has just quitted its corresponding one *af*. The same effect may be produced by toothed wheels upon all the arbors, as shown in fig. 2.

Each arbor *a*, *a*, *a*, *a*, the number of which depends on the circumstances of the case, carries a drum *ttrr*, round which is coiled a cord passing over a pulley *p*, and sustaining a weight Q, which slides upon the lever FG, upon any part

[1] This has been demonstrated by Mr Atwood. See his Treatise on Rectilineal and Rotatory Motion.
[2] Economy of Manufactures, § 20.
[3] See Lanz and Betancourt's *Essai sur Machines*, p. 84.

On the Teeth of Wheels.

of which it may be fixed, G being the fulcrum of the lever. The axis *a* passes loosely through the pinion *gg*, which carries a click or ratchet bearing against teeth upon the side *rr* of the drum, so that when the weight Q tends to rise, the ratchet gives way, *gg* is thrown loose, and the weight Q continues to rise. When the arm *bd* has ceased to act upon *af*, the weight Q rises no further, but tends to descend. The ratchet is then thrown into the teeth of *rr*, so that, in descending, Q turns the pinion *gg* along with the drum *ttrr*. The very same thing is going on with all the other arbors, which are raising other weights Q, which re-descend in their turn, and give motion to their corresponding pinions *gg*.

Now *gg* drives the wheel AB, which, by means of the bevelled wheel on its lower side GD acting upon the bevelled wheel CF, raises the bucket or weight P, which is the work to be performed. Hence the descent of all the weights Q, Q, &c. will concur in raising P. By regulating the distance of the weights Q from the centre of motion G, the proper ratio between the power of the work to produce a maximum effect may be obtained.

Baron Prony justly remarks, that advantage may be taken of the weakest breezes to obtain a certain effect, when all other wind-mills are inactive.[1]

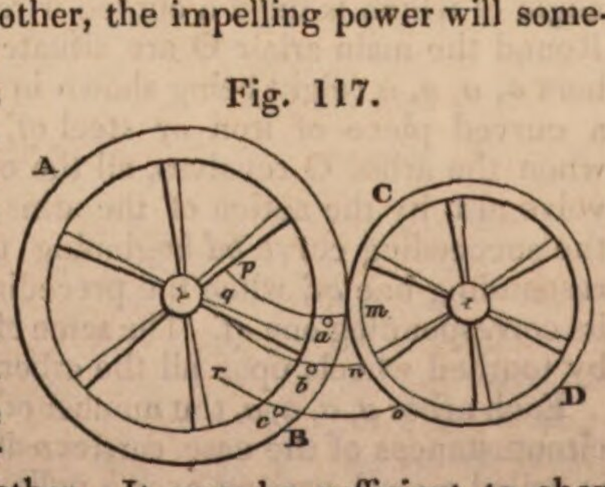
Rev. Mr Cecil's regulator.

A very ingenious regulator for equalizing the velocity of machinery has been described by the Rev. W. Cecil, of Magdalen College, Cambridge. If we suppose two wheels to be so connected that an increase in the velocity of the first is accompanied with an increase in the velocity of the second in the *same ratio*, and if these wheels have another connection, by means of which an increase in the velocity of the first is accompanied by an increase in the velocity of the second in a higher ratio, then it will be impossible that any increase should take place, as it would require the second to move with two different velocities at once. These conditions may be fulfilled by connecting the wheels in the first instance by common teeth-work, and, in the next place, by another toothed wheel, which slides into different positions as the centrifugal force varies. By these means Mr Cecil gets a regulator which opposes no resistance up to a certain velocity, but which, at all greater velocities, presents an insurmountable resistance to any augmentation of velocity, and which may be readily united to any revolving machinery, whatever be its construction and power, the velocity of which it is required to equalize.

CHAP. V.—ON THE TEETH OF WHEELS AND THE WIPERS OF STAMPERS.

In the construction of machines, we must not only attend to the form and number of their parts, but also to the mode by which they are to be connected. It would be easy to show, did the limits of this article permit it, that, when one wheel impels another, the impelling power will sometimes act with greater and sometimes with less force, unless the teeth of one or both of the wheels be parts of a curve generated after the manner of an epicycloid, by the revolution of one circle along the convex or concave side of another. It may be sufficient to show that, when one wheel impels another by the action of

Fig. 117.



epicycloidal teeth, their motion will be uniform. Let the wheel CD drive the wheel AB by means of the epicycloidal teeth *mp*, *nq*, *or*, acting upon the infinitely small pins or spindles *a*, *b*, *c*; and let the epicycloids *mp*, *nq*, &c. be generated by the circumference of the wheel AB, rolling upon the convex circumference of the wheel CD. From the formation of the epicycloid, it is obvious that the arch *ab* is equal to *mn*, and the arch *ac* to *mo*; for during the formation of the part *nb* of the epicycloid *nq*, every point of the arch *ab* is applied to every point of the arch *mn*; and the same happens during the formation of the part *co* of the epicycloid *or*. Let us now suppose that the tooth *mp* begins to act on the pin *a*, and that *b*, *c* are successive positions of the pin *a* after a certain time; then *nq*, *or* will be the positions of the tooth *mp* after the same time; but $ab = mn$ and $ac = mo$, therefore the wheels AB, CD, when the arch is driven by epicycloidal teeth, move through equal spaces in equal times, that is, the force of the wheel CD, and the velocity of the wheel AB, are always uniform.

On the Teeth of Wheels.

In illustrating the application of this property of the epicycloid, which was discovered by Olaus Roemer, the celebrated Danish astronomer, we shall call the small wheel the *pinion*, and its teeth the *leaves* of the pinion. The line which joins the centre of the wheel and pinion is called the *line of centres*. There are three different ways in which the teeth of one wheel may drive another, and each of these modes of action requires a different form for the teeth.

1. When the action is begun and completed after the teeth have passed the line of centres.

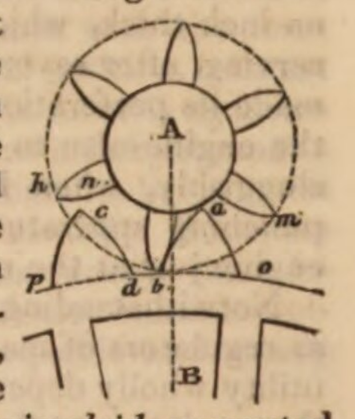
2. When the action is begun and completed before they reach the line of centres.

3. When the action is carried on, on both sides of the line of centres.

First mode of action.

1. The first of these modes of action is represented in fig. 118, where B is the centre of the wheel,[2] A that of the pinion, and AB the line of centres. It is evident from the figure, that the part *b* of the tooth *ab* of the wheel does not act on the leaf *m* of the pinion till they arrive at the line of centres AB, and that all the action is carried on after they have passed this line, and is completed when the leaf *m* comes into the situation *n*. When this mode of action is adopted, the acting faces of the leaves of the pinion should be parts of an *interior epicycloid*, generated by a circle of any diameter rolling upon the concave superficies of the pinion, or within the circle *adh*; and the faces *ab* of the teeth of the wheel should be portions of an *exterior epicycloid*, formed by the *same* generating circle rolling upon the convex superficies *odp* of the wheel.

Fig. 118.



But when one circle rolls within another whose diameter is double that of the rolling circle, the line generated by any point of the latter is a *straight line* tending to the centre of the larger circle. Therefore, if the generating circle above mentioned should be taken with its diameter equal to the radius of the pinion, and be made to roll upon the concave superficies *adh* of the pinion, it will generate a straight line tending to the pinion's centre, which will be the form of the faces of its leaves; and the teeth of the wheel will be exterior epicycloids, formed by a generating circle whose diameter is equal to the radius of the pinion, rolling upon the convex superficies *odp* of the wheel. This rectilineal form of the teeth is exhibited in

[1] See *Annales des Arts et Manufactures*, tom. xix.

[2] In figs. 109, 110, 111, 112, the letter B is supposed to be placed at the centre of the wheels.

On the Teeth of Wheels.

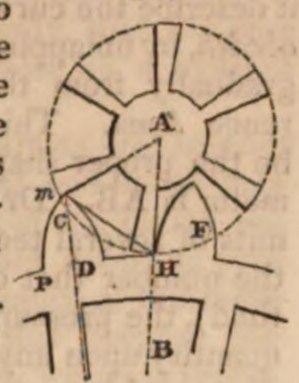
fig. 119, and is perhaps the most advantageous, as it requires less trouble, and may be executed with greater accuracy, than if the epicycloidal form had been employed, though the teeth are evidently weaker than those in fig. 118. It is recommended both by De la Hire and Camus as particularly advantageous in clock and watch work.

The attentive reader will perceive from fig. 118, that in order to prevent the teeth of the wheel from acting upon the leaves of the pinion before they reach the line of centres AB, and that one tooth of the wheel may not quit the leaf of the pinion till the succeeding tooth begins to act upon the succeeding leaf, there must be a certain proportion between the number of leaves in the pinion and the number of teeth in the wheel, or between the radius of the pinion and the radius of the wheel, when the distance of the leaves AB is given. But in machinery the number of leaves and teeth is always known from the velocity which is required at the working point of the machine; it becomes therefore a matter of great importance to determine with accuracy the relative radii of the wheel and pinion.

Relative size of the wheel and pinion.

For this purpose, let A, fig. 119, be the pinion having the acting faces of its leaves straight lines tending to the centre, and B the centre of the wheel. AB will be the distance of their centres. Then, as the tooth C is supposed not to act upon the leaf *Am* till it arrives at the line AB, it ought not to quit *Am* till the following tooth F has reached the line AB. But since the tooth always acts in the direction of a line drawn perpendicular to the face of the leaf *Am* from the point of contact, the line CH, drawn at right angles to the face of the leaf *Am*, will determine the extremity of the tooth CD, or the last part of it which should act upon the leaf *Am*, and will also mark out CD for the depth of the tooth. Now, in order to find AH, HB, and CD, put a for the number of teeth in the wheel, b for the number of leaves in the pinion, c for the distance of the pivots A and B, and let x be the radius of the wheel, and y that of the pinion. Then, since the circumference of the wheel is to the circumference of the pinion as the number of teeth in the one to the number of leaves in the other, and as the circumferences of circles are proportional to their radii, we shall have $a : b = x : y$; then, by composition (Eucl. v. 18), $a + b : b = c : y$ (c being equal to $x + y$), and consequently the radius of the pinion, viz. $y = \frac{cb}{a+b}$; then, by inverting the first analogy, we have $b : a = y : x$, and consequently the radius of the wheel, viz. $x = \frac{ay}{b}$; y being now a known number.

Fig. 119.



Now, in the triangle AHC, right-angled at C, the side AH is known, and likewise all the angles (HAC being equal to $\frac{360}{b}$); the side AC, therefore, may be found by plain trigonometry. Then, in the triangle ACB, the $\angle$CAB, equal to HAC, is known, and also the sides AB, AC, which contain it; the third side, therefore, viz. CB, may be determined; from which DB, equal to HB, already found, being subtracted, there will remain CD for the depth of the teeth. When the action is carried on after the line of centres, it often happens that the teeth will not work in the hollows of the leaves. In order to prevent this, the $\angle$CBH must always be greater than half the $\angle$HBP. The $\angle$HBP is equal to 360 degrees, divided by the number of teeth in the wheel, and CBH is easily found by plane trigonometry.

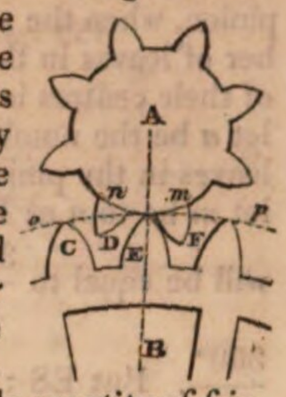
If the teeth of wheels and the leaves of pinions be formed according to the directions already given, they will act upon each other, not only with uniform force, but nearly without friction. The one tooth rolls upon the other, and neither slides nor rubs to such a degree as to retard the wheels or wear their teeth. But as it is impossible in practice to give that perfect curvature to the faces of the teeth which theory requires, a quantity of friction will remain after every precaution has been taken in the formation of the communicating parts.

On the Teeth of Wheels.

2. The second mode of action is not so advantageous as that which we have been considering, and should, if possible, always be avoided. It is represented in fig. 120, where A is the centre of the pinion, B that of the wheel, and AB the line of the centres. It is evident from the figure, that the tooth C of the wheel acts upon the leaf D of the pinion before they arrive at the line BA; that it quits the leaf when they reach this line, and have assumed the position of E and F; and that the tooth C works deeper and deeper between the leaves of the pinion, the nearer it comes to the line of centres. From this last circumstance a considerable quantity of friction arises, because the tooth C does not, as before, roll upon the leaf D, but slides upon it; and from the same cause the pinion soon becomes foul, as the dust which lies upon the acting faces of the leaves is pushed into the interjacent hollows. One advantage, however, attends this mode of action: it allows us to make the teeth of the large wheel rectilineal, and thus renders the labour of the mechanic less, and the accuracy of his work greater, than if they had been of a curvilineal form. If the teeth C, E therefore of the wheel BC are made rectilineal, having their surfaces directed to the wheel's centre, the acting faces of the leaves D, F, &c. must be epicycloids formed by a generating circle whose diameter is equal to the radius B*o* of the circle *op*, rolling upon the circumference *mn* of the pinion A. But if the teeth of the wheel and the leaves of the pinion are made curvilineal as in the figure, the faces of the teeth of the wheel must be portions of an interior epicycloid formed by any generating circle rolling within the concave superficies of the circle *op*, and the faces of the pinion's leaves must be portions of an exterior epicycloid produced by rolling the same generating circle upon the convex circumference *mn* of the pinion.

Second mode of action.

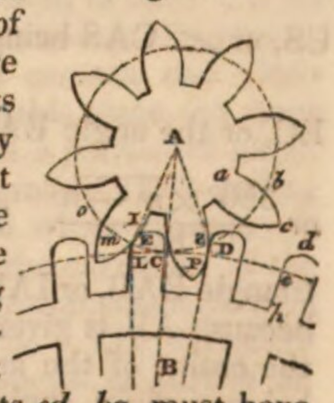
Fig. 120.



3. The third mode of action, which is represented in fig. 121, is a combination of the first two modes, and consequently partakes of the advantages and disadvantages of each. It is evident from the figure that the portion *eh* of the tooth acts upon the part *bc* of the leaf till they reach the line of centres AB, and that the part *ed* of the tooth acts upon the portion *ba* of the leaf after they have passed this line. Hence the acting parts *eh* and *bc* must be formed according to the directions given for the first mode of action, and the remaining parts *ed*, *ba*, must have that curvature which the second mode of action requires; consequently *eh* should be part of an interior epicycloid formed by any generating circle rolling on the concave circumference *mn* of the wheel, and the corresponding part *bc* of the leaf should be part of an exterior epicycloid formed by the same generating circle rolling upon *bEo*, the convex circumference of the pinion; the remaining part *ed* of the tooth should be a portion of an exterior epicycloid, engendered by any generating circle rolling upon *e*L, the concave superficies of the wheel; and the corresponding part *ba* of the leaf should be part of an interior epicycloid described by the same generating circle, rolling along the

Third mode of action

Fig. 121.



On the Teeth of Wheels.

concave side *b*E*o* of the pinion. As it would be extremely troublesome, however, to give this double curvature to the acting faces of the teeth, it will be proper to use a generating circle, whose diameter is equal to the radius of the wheel BC, for describing the interior epicycloid *eh*, and the exterior one *bc*; and a generating circle, whose diameter is equal to AC, the radius of the pinion, for describing the interior epicycloid *ba*, and the exterior one *ed*. In this case the two interior epicycloids *eh*, *ba* will be straight lines tending to the centres B and A, and the labour of the mechanic will by this means be greatly abridged.

Relative diameters of the wheel and pinion.

In order to find the relative diameters of the wheel and pinion, when the number of teeth in the one and the number of leaves in the other are given, and when the distance of their centres is also given, and the ratio of ES to CS, let a be the number of teeth in the wheel, b the number of leaves in the pinion, c the distance of the pivots A, B, and let m be to n as ES to CS; then the arch ES, or $\angle$SAE, will be equal to $\frac{360^\circ}{b}$, and LD, or $\angle$LBD, will be equal to $\frac{360^\circ}{a}$. But ES : CS $= m : n$; consequently LD : LC $= m : n$, therefore (Eucl. vi. 16) LC $\times m =$ LD $\times n$, and LC $= \frac{\text{LD} \times n}{m}$; but LD is equal to $\frac{360^\circ}{a}$, therefore, by substitution, LC $= \frac{360 \times n}{am}$.

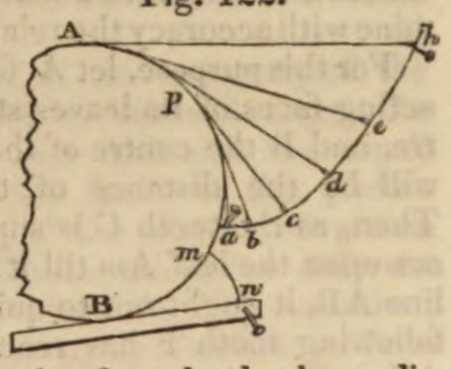
Now, in the triangle APB, AB is known, and also PB, which is the cosine of the angle ABD, PC being perpendicular to DB; AP or the radius of the pinion, therefore, may be found by plain trigonometry. The reader will observe that the point P marks out the parts of the tooth D and the leaf SP where they commence their action; and the point I marks out the parts where their mutual action ceases;[1] AP therefore is the proper radius of the pinion, and BI the proper radius of the wheel, the parts of the tooth L without the point I, and of the leaf SP without the point P, being superfluous. Now, to find BI, we have ES : CS $= m : n$, and CS $= \frac{\text{ES} \times n}{m}$; but ES was shown to be $= \frac{360}{b}$, therefore, by substitution, CS $= \frac{360 \times n}{bm}$. Now the arch ES, or $\angle$ EAS, being equal to $\frac{360}{b}$, and CS, or $\angle$ CAS being equal to $\frac{360 \times n}{bm}$, their difference EC, or the angle EAC, will be equal to $\frac{360}{b} - \frac{360 \times n}{bm}$, or $\frac{360^\circ \times \overline{m-n}}{bm}$. The $\angle$ EAC being thus found, the triangle EAB, or IAB, which is almost equal to it, is known, because AB is given, and likewise AI, which is equal to the cosine of the angle IAB, AC being radius, and AIC being a right angle, consequently IB the radius of the wheel may be found by trigonometry. It was formerly shown that AC, the radius of what is called the primitive pinion, was equal to $\frac{cb}{a+b}$, and that BC the radius of the primitive wheel was equal to $\frac{\text{AC} \times a}{b}$. If then we subtract AC or AS from AP, we shall have the quantity SP, which must be added to the radius of the primitive pinion; and if we take the difference of BC (or BL) and DE, the quantity LE will be found, which must be added to the radius of the primitive wheel. We have all along supposed that the wheel drives the pinion, and have given the proper form of the teeth upon this supposition. But when the pinion drives the wheel, the form which was given to the teeth of the wheel in the first case must in this be given to the leaves of the pinion; and the shape which was formerly given to the leaves of the pinion must now be transferred to the teeth of the wheel.

On the Teeth of Wheels.

Form of the teeth according to Dr Robison.

Another form for the teeth of wheels, different from any which we have mentioned, has been recommended by Dr Robison. He shows that a perfect uniformity of action may be secured, by making the acting faces of the teeth involutes of the wheel's circumference, which are nothing more than epicycloids, the centres of whose generating circles are infinitely distant. Thus, in fig. 122, let AB be a portion of the wheel on which the tooth is to be fixed, and let *Apa* be a thread lapped round its circumference, having a loop-hole at its extremity *a*. In this loop-hole fix the pin *a*, and with it describe the curve or *involute abcdeh*, by unlapping the thread gradually from the circumference *Apm*. This curve will be the proper shape for the teeth of a wheel whose diameter is AB. Dr Robison observes, that as this form admits of several teeth to be acting at the same time (twice the number that can be admitted in M. de la Hire's method), the pressure is divided among several teeth, and the quantity upon any one of them is so diminished, that those dents and impressions which they unavoidably make upon each other are partly prevented. He candidly allows, however, that the teeth thus formed are not completely free from sliding and friction, though this slide is only $\frac{1}{60}$th of an inch when a tooth three inches long fixed on a wheel ten feet in diameter drives another wheel whose diameter is two feet. (Append. to Ferguson's *Lectures*.)

Fig. 122.

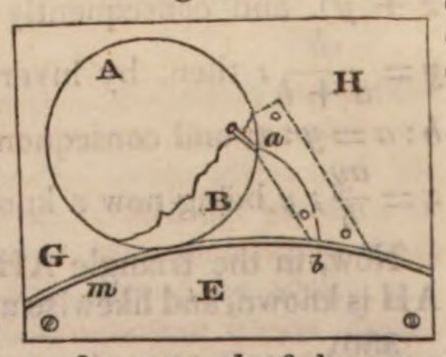


On the Formation of Exterior and Interior Epicycloids, and on the Disposition of the Teeth on the Wheel's Circumference.

Mechanical method of forming epicycloids.

Nothing can be of greater importance to the practical mechanic, than to have a method of drawing epicycloids with facility and accuracy: the following, we trust, is the most simple mechanical method that can be employed.—Take a piece of plain wood GH, fig. 123, and fix upon it another piece of wood E, having its circumference *mb* of the same curvature as the circular base upon which the generating circle AB is to roll. When the generating circle is large, the segment B will be sufficient: in any part of the circumference of this segment fix a sharp-pointed nail *a*, sloping in such a manner that the distance of its point from the centre of the circle may be exactly equal to its radius; and fasten to the board GH a piece of thin brass, or copper, or tin plate, *ab*, distinguished by the dotted lines. Place the segment B in such a position that the point of the nail *a* may be upon the point *b*, and roll the segment towards G, so that the nail *a* may rise gradually, and the

Fig. 123.

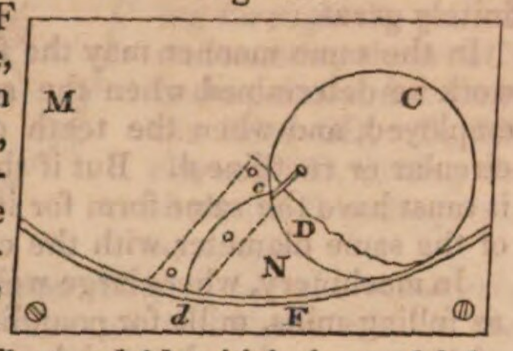


[1] The letter L marks the intersection of the line BL with the arch *em*, and the letter E the intersection of the arch *b*O with the upper surface of the leaf *m*. The letters D and S correspond with L and E respectively, and P with I.

On the Teeth of Wheels.

point of contact between the two circular segments may advance towards *m*; the curve *ab* described upon the brass plate will be an accurate exterior epicycloid. In order to prevent the segments from sliding, their peripheries should be rubbed with rosin or chalk, or a number of small iron points may be fixed on the circumference of the generating segment. Remove, with a file, the part of the brass on the left hand of the epicycloid, and the remaining concave arch or gage *ab* will be a pattern tooth, by means of which all the rest may be easily formed. When an *interior epicycloid* is wanted, the concave side of its circular base must be used. The method of describing it is represented in fig. 124, where CD is the generating circle, F the concave circular base, MN the piece of wood on which this base is fixed, and *cd* the interior epicycloid formed upon the plate of brass by rolling the generating circle C, or the generating segment D, towards the right hand. The *cycloid*, which is useful in forming the teeth of *rack-work*, is generated precisely in the same manner, with this difference only, that the base on which the generating circle rolls must be a straight line.

Fig. 124.



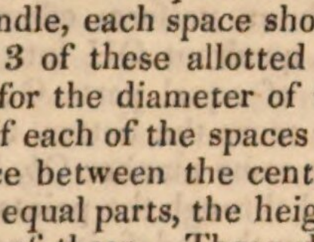
In order that the teeth may not embarrass one another before their action commences, and that one tooth may begin to act upon its corresponding leaf of the pinion before the preceding tooth has ceased to act upon the preceding leaf, the height, breadth, and distance of the teeth must be properly proportioned. For this purpose the pitch-line or circumference of the wheel, which is represented in fig. 119 and 120, by the dotted arches, must be divided into as many equal spaces as the number of teeth which the wheel is to carry. Divide each of these spaces into 16 equal parts; allow 7 of these for the greatest breadth of the teeth, and 9 for the distance between each; or the distance of the teeth may be made equal to their breadth. If the wheel drive a trundle, each space should be divided into 7 equal parts, and 3 of these allotted for the thickness of the tooth, and $3\frac{4}{5}$ for the diameter of the cylindrical stave of the trundle. If each of the spaces already mentioned, or if the distance between the centres of each tooth, be divided into three equal parts, the height of the teeth must be equal to two of these. These distances and heights, however, vary according to the mode of action which is employed. The teeth should be rounded off at the extremities, and the radius of the wheel made a little larger than that which is deduced from the rules in p. 421–22. But when the pinion drives the wheel, a small addition should be made to the radius of the pinion.

On the Nature of Bevelled Wheels, and the Method of giving an Epicycloidal Form to their Teeth.

Bevelled wheels.

The principle of bevelled wheels was pointed out by De la Hire, so long ago as the end of the seventeenth century. It consists in one fluted or toothed cone acting upon another, as is represented in fig. 125, where the cone OD drives the cone OC, conveying its motion in the direction OC. If these cones be cut parallel to their bases, as at A and B, and if the two small cones between AB and O be removed, the remaining parts AC and BD may be considered as two bevelled wheels, and BD will act upon AC in the very same manner, and with the same effect, that the whole cone OD acted upon the whole cone OC. If the section be made nearer the bases of the cones, the same effect will be produced. This is the case in fig. 126, where CD and DE are but very small portions of the imaginary cones ACD and ADE.

Fig. 125.



In order to convey motion in any given direction, and determine the relative size and situation of the wheels for this purpose, let AB, fig. 127, be the axis of a wheel, and CD the given direction in which it is required to convey the motion by means of a wheel fixed upon the axis AB, and acting upon another wheel fixed on the axis CD; and let us suppose that the axis CD must have four times the velocity of AB, or must perform four revolutions while AB performs one. Then the number of teeth in the wheel fixed upon AB must be four times greater than the number of teeth in the wheel fixed upon CD, and their radii must have the same proportion. Draw *cd* parallel to CD at any convenient distance, and draw *ab* parallel to AB at four times that distance, then the lines *im* and *in* drawn perpendicular to AB and CD respectively will mark the situation and size of the wheels required. In this case the cones are *Oni* and *Omi*, and *srni*, *rpmi* are the portions of them that are employed.

Fig. 126.

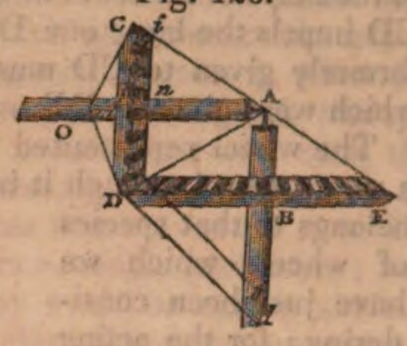
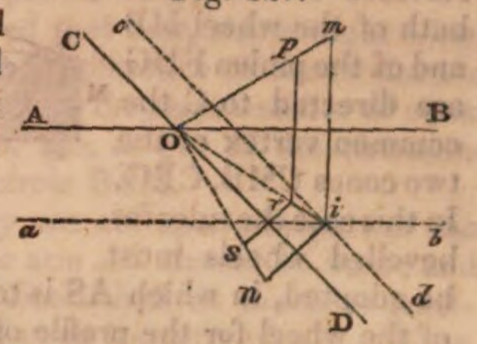


Fig. 127.



On the formation of their teeth.

The formation of the teeth of bevelled wheels is more difficult than one would at first imagine. The teeth of such wheels, indeed, must be formed by the same rules which have been given for other wheels; but since different parts of the same tooth are at different distances from the axis, these parts must have the curvature of their acting surfaces proportioned to that distance. Thus, in fig. 127, the part of the tooth at *r* must be more incurvated than the part at *i*, as is evident from the inspection of fig. 126; and the epicycloid for the part *i* must be formed by means of circles whose diameters are *im* and F*f*, while the epicycloid for the part *r* must be generated by circles whose diameters are C*n* and D*d*.

Let us suppose a plane to pass through the points O, A, D; the lines AB, AO will evidently be in this plane, which may be called the *plane of centres*. Now, when the teeth of the wheel DE, which is supposed to drive CD the smallest of the two, commence their action on the teeth of CD when they arrive at the plane of centres, and continue their action after they have passed this plane, the curve given to the teeth CD at C, should be a portion of an interior epicycloid formed by any generating circle rolling on the concave superficies of a circle whose diameter is twice C*n* perpendicular to CA, and the curvature of the teeth at *i* should be part of a similar epicycloid formed upon a circle whose diameter is twice *im*. The curvature of the teeth of the wheel DE, at D, should be part of an exterior epicycloid formed by the same generating circle rolling upon the concave circumference of a circle whose diameter is twice D*d* perpendicular to DA; and the epicycloid for the teeth at F is formed in the same way, only, instead of twice D*d*, the diameter of the circle must be twice F*f*. When any other mode of action is adopted, the teeth are to be formed in the same manner that we have pointed out for common wheels, with this difference only, that different epicycloids are necessary for the parts F and D. It may be sufficient, however, to find the form of the teeth at F, as the remaining part of the tooth may be shaped by directing a straight ruler from different points of the epicycloid at F to the centre A, and filing the tooth till every

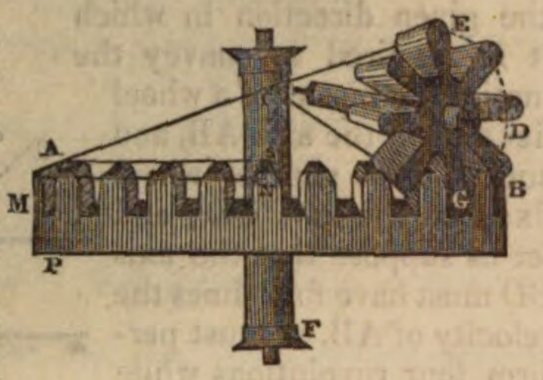
On the Wipers of Stampers.

part of its acting surface coincide with the side of the ruler. The reason of this operation will be obvious by attending to the shape of the tooth in fig. 125. When the small wheel CD impels the large one DE, the epicycloids which were formerly given to CD must be given to DE, and those which were given to DE must be transferred to CD.

On crown wheels.

The wheel represented in fig. 128 is sometimes called a crown wheel, though it is evident from the figure that it belongs to that species of wheels which we have just been considering; for the acting surfaces of the teeth both of the wheel MB and of the pinion EDG are directed to C the common vertex of the two cones CMB, CEG. In this case the rules for bevelled wheels must be adopted, in which AS is to be considered as the radius of the wheel for the profile of the tooth at A, and MN as its radius for the profile of the tooth at M; and the epicycloids thus formed will be the sections or profiles of the teeth in the direction MP, at right angles to MC the surfaces of the cone. When the vertex C of the cone MCG approaches to N till it be in the same place with the points M, G, some of the curves will be cycloids and others involutes, as in the case of rack-work, for then the cone CEG will revolve upon a plane surface. (Appendix to Ferguson's *Lectures*.)

Fig. 128.



Sect. II.—*On the Wipers of Stampers, &c. the Teeth of Rack-work, &c. &c.*

On the wipers of stampers.

In fig. 129 let AB be the wheel which is employed to elevate the rack C, and let their mutual action not commence till the acting teeth have reached the line of centres AC. In this case C becomes as it were the pinion or wheel driven, and the acting faces of its teeth must be *interior epicycloids* formed by any generating circle rolling within the circumference *pq*; but as *pq* is a straight line, these interior epicycloids will be *cycloids*, or curves generated by a point in the circumference of a circle rolling upon a straight line or plane surface. The acting face *op*, therefore, will be part of a *cycloid* formed by any generating circle, and *mn*, the acting face of the teeth of the wheel, must be an *exterior* epicycloid produced by the same generating circle rolling on *mr* the convex surface of the wheel. If it be required to make *op* a straight line, as in the figure, then *mn* must be an *involute* of the circle *mr* formed in the manner represented in fig. 122.

Fig. 129.

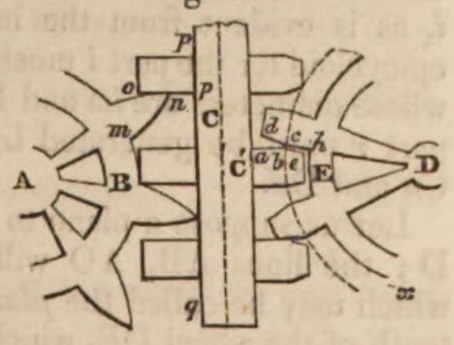


Fig. 129 likewise represents a wheel depressing the rack C′ when the third mode of action is used. In this case also C′ becomes the pinion, and DE the wheel; *eh* therefore must be part of an interior epicycloid formed by any generating circle rolling on the concave side *ex* of the wheel, and *bc* must be an exterior epicycloid produced by the same generating circle rolling upon the circumference of the rack. The remaining part *cd* of the teeth of the wheel must be an exterior epicycloid described by any generating circle moving upon the convex side *ex*, and *ba* must be an interior epicycloid engendered by the same generating circle rolling within the circumference of the rack. But as the circumference of the rack is in this case a straight line, the exterior epicycloid *bc* and the interior one *ba* will be cycloids formed by the same generating circles which are employed in describing the other epicycloids. Since it would be difficult, however, as has already been remarked, to give this compound curvature to the teeth of the wheel and rack, we may use a generating circle whose diameter is equal to D*x* the radius of the wheel, for describing the interior epicycloid *eh*, and the exterior one *bc*; and a generating circle whose diameter is equal to the radius of the rack, for describing the interior epicycloid *ab*, and the exterior one *de*; *ab* and *eh*, therefore, will be straight lines, and *bc* will be a cycloid and *de* an involute of the circle *ex*, the radius of the wheel being infinitely great.

On the Wipers of Stampers.

In the same manner may the form of the teeth of rack-work be determined when the second mode of action is employed, and when the teeth of the wheel or rack are circular or rectilineal. But if the rack be part of a circle, it must have the same form for its teeth as that of a wheel of the same diameter with the circle of which it is a part.

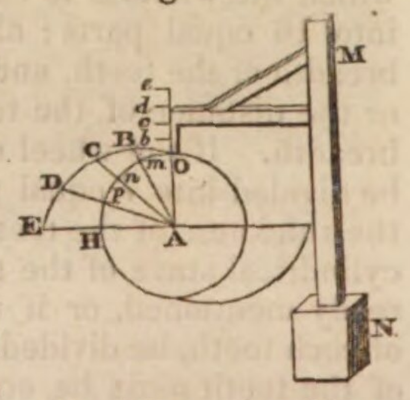
Proper form of wipers.

In machinery, where large weights are to be raised, such as fulling-mills, mills for pounding ore, &c. or where large pistons are to be elevated by the arms of levers, it is of the greatest consequence that the power should raise the weight with an uniform force and velocity; and this can be effected only by giving a proper form to the wiper.

Now there are two cases in which this uniformity of motion may be required, and each of these demands a different form for the communicating parts: 1. When the weight is to be raised vertically, as the piston of a pump, &c.; 2. when the weight to be raised or depressed moves upon a centre, and rises or falls in the arch of a circle, such as the sledge-hammer in a forge, &c.

1. Let AH be a wheel moved by any power which is sufficient to raise the weight MN by its extremity O, from O to *e*, in the same time that the wheel moves round one fourth of its circumference; it is required to fix upon its rim a wing OBCDEH, which shall produce this effect with an uniform effort. Divide the quadrant OH into any number of equal parts O*m*, *mn*, &c. the more the better, and O*e* into the same number O*b*, *bc*, *cd*, &c.; and through the points *m*, *n*, *p*, H draw the indefinite lines AB, AC, AD, AE, and make AB equal to A*b*, AC to A*c*, AD to A*d*, and AE to A*e*; then through the points O, B, C, D, E, draw the curve OBCDE, which is a portion of the spiral of Archimedes, and will be the proper form for the wiper or wing OHE. It is evident, that when the point *m* has arrived at O, the extremity of the weight will have arrived at *b*, because AB is equal to A*b*; and, for the same reason, when the points *n*, *p*, H have successively arrived at O, the extremity of the weight will have arrived at the corresponding points *c*, *d*, *e*. The motion, therefore, will be uniform, because the space described by the weight is proportional to the space described by the moving power, O*b* being to O*c* as O*m* to O*n*. If it be required to raise the weight MN with an accelerated or retarded motion, we have only to divide the line O*e* according to the law of acceleration or retardation, and divide the curve OBCDE as before.

Fig. 130.



When the weight rises in the arch of a circle.

2. When the lever moves upon a centre, the weight will rise in the arch of a circle, and consequently a new form must be given to the wipers or wings. Let AB, fig. 131, be a lever lying horizontally, which it is required to raise uniformly through the arch BC into the position AC, by means of the wheel BFH furnished with the wing BNOP, which acts upon the extremity C of the lever; and let it

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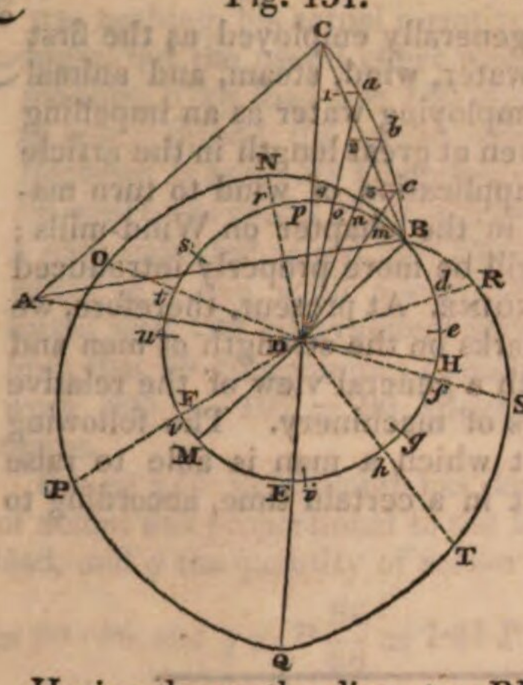
be required to raise it through BC in the same time that the wheel BFH moves through one half of its circumference; that is, while the point M moves to B in the direction MFB. Divide the chord CB into any number of equal parts, the more the better, in the points 1, 2, 3, and draw the lines 1*a* 2*b*, 3*c*, parallel to AB, or a horizontal line passing through the point B, and meeting the arch CB in the points *a*, *b*, *c*. Draw the lines CD, *a*D, *b*D, *c*D, and BD, cutting the circle BFH in the points *m*, *n*, *o*, *p*.

Fig. 131.



Having drawn the diameter BM, divide the semicircle BFM into as many equal parts as the chord CB, in the points *q*, *s*, *u*. Take B*m*, and set it from *q* to *r*; take B*n* and set it from *s* to *t*; take B*o* and set it from *u* to *v*; and, lastly, set B*p* from M to E. Through the points *r*, *t*, *v*, E, draw the indefinite lines DN, DO, DP, DQ, and make DN equal to D*c*, DO equal to D*b*, DP equal to D*a*, and DQ equal to DC. Then through the points Q, P, O, N, B, draw the spiral BNOPQ, which will be the proper form for the wing of the wheel when it moves in the direction EMB.

That the spiral BNO will raise the lever AC, with an uniform motion, by acting upon its extremity *c*, will appear from the slightest attention to the construction of the figure. It is evident, that when the point *q* arrives at B, the point *r* will be in *m*, because B*m* is equal to *qr*, and the point N will be at *c*, because DN is equal to D*c*; the extremity of the lever therefore will be found in the point *c*, having moved through B*c*. In like manner, when the point *s* has arrived at B, the point *t* will be at *n*, and the point O in *b*, where the extremity of the lever will now be found; and so on with the rest, till the point M has arrived at B. The point E will then be in *p*, and the point Q in C; so that the lever will now have the position AC, having moved through the equal heights B*c*, *cb*, *ba*, *ac*,[1] in the same time that the power has moved through the equal spaces *q*B, *sq*, *us*, M*u*. The lever therefore has been raised uniformly, the ratio between the velocity of the power and that of the weight remaining always the same.

If the wheel D turn in a contrary direction, according to the letters MHB, we must divide the semicircle BHEM, into as many equal parts as the chord *c*B, viz. in the points *e*, *g*, *h*. Then, having set the arch B*m* from *e* to *d*, the arch B*n* from *g* to *f*, and the rest in a similar manner, draw, through the points *d*, , *h*, E, the indefinite lines DR, DS, DT, DQ: make DR equal to D*c*, DS equal to D*b*, DT equal to D*a*, and DQ equal to DC; and through the points B, R, S, T, Q, describe the spiral BRSTQ, which will be the proper form for the wing when the wheel turns in the direction MEB. For, when the point *e* arrives at B, the point *d* will be in *m*, and R in *c*, where the extremity of the lever will now be found, having moved through B*c* in the same time that the power or wheel has moved through the division *e*B. In the same manner it may be shown, that the lever will rise through the equal heights *cb*, *ba*, *a*C, in the same time that the power moves through the corresponding spaces *eg*, *gi*, *i*M. The motion of the lever, therefore, and also that of the power, are always uniform. Of all the positions that can be given to the point B, the most disadvantageous are those which are nearest the points F, H; and the most advantageous position is when the chord B*c* is vertical, and passes, when prolonged, through D, the centre of the circle.[2] In this particular case, the two curves have equal bases, though they differ a little in point of curvature. The farther that the centre A is distant, the nearer do these curves resemble each other; and if it were infinitely distant, they would be exactly similar, and would be the spirals of Archimedes, as the extremity *c* would in this case rise perpendicularly.

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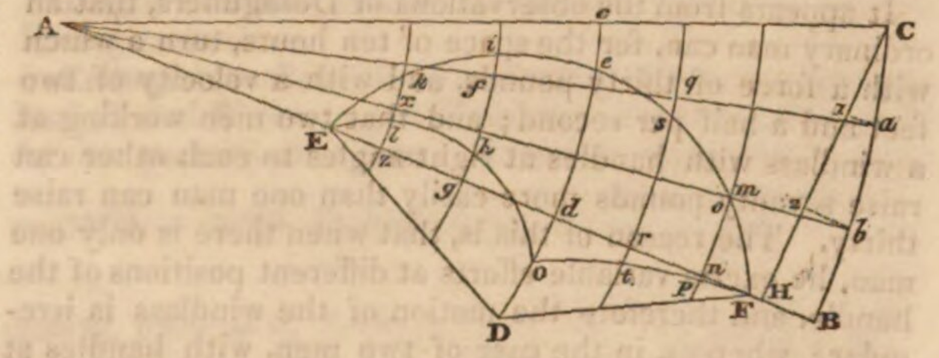
It will be easily perceived that four, six, or eight wings may be placed upon the circumference of the circle, and may be formed by dividing into the same number of equal parts as the chord BC, $\frac{1}{4}$th, $\frac{1}{6}$th, or $\frac{1}{8}$th of the circumference, instead of the semicircle BFM.

That the wing BNO may not act upon any part of the lever between A and C, the arm AC should be bent; and that the friction may be diminished as much as possible, a roller should be fixed upon its extremity C. When a roller is used, however, a curve must always be drawn parallel to the spiral described according to the preceding method, the distance between it and the spiral being everywhere equal to the radius of the roller.

If it should be required to raise the lever with an accelerated or retarded motion, we have only to divide the chord BC, according to the degree of retardation or acceleration required, and the circle into the same number of equal parts as before.

As it is frequently more convenient to raise or depress weights by the extremity of a constant radius, furnished with a roller, instead of wings fixed upon the periphery of a wheel, we shall now proceed to determine the curve which must be given to the arm of the lever which is to be raised and depressed, in order that this elevation or depression may be effected with an uniform motion.

Fig. 132.



Let AB, fig. 132, be a lever, which it is required to raise uniformly through the arch BC, into the position AC, by means of the arm or constant radius DE, moving upon D as a centre, in the same time that the extremity E describes the arch E*e*F. From the point C draw CH at right angles to AB, and divide it into any number of equal parts, suppose three, in the points 1, 2; and through the points 1, 2, draw 1*a*2*b*, parallel to the horizontal line AB, cutting the arch CB in the points *a*, *b*, through which draw *a*A, *b*A. Upon D as a centre, with the distance DE, describe the arch E*ie*F, and upon A as a centre, with the distance AD, describe the arch *e*OD, cutting the arch E*ie*F in the point *e*. Divide the arches E*ie* and F*se*, each into the same number of equal parts as the perpendicular *c*H, in the points *k*, *i*, *s*, *m*, and through these points about the centre A describe the arches *kz*, *ig*, *qr*, *mn*. Take *zx*

[1] The arches B*c*, *cb*, &c. are not equal; but the perpendiculars let fall from the points *c*, *a*, *b*, &c. upon the horizontal lines passing through *a*, *b*, &c. are equal, being proportional to equal lines *c*1, 1, 2. Eucl. vi. 2.

[2] In the figure, we have taken the point B in a disadvantageous position, because the intersections are in this case more distinct.

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and set it from *k* to *l*, and take *gf*, and set it from *i* to *h*. Take *rq*, also, and set it from *s* to *t*, and set *nm* from *o* to *p*, and *dc* from *e* to O. Then through the points E, *l*, *h*, O, and O, *t*, *p*, F, draw the two curves E*l*h*h*O, and O*tp*F, which will be the proper form that must be given to the arm of the lever. If the handle DE moves from E towards F, the curve EO must be used; but if in the contrary direction, we must employ the curve OF.

It is evident, that when the extremity E of the handle DE has run through the arch E*k*, or rather E*l*, the point *l* will be in *k*, and the point *z* in *x*, because *xz* is equal to *kl*, and the lever will have the position A*b*. For the same reason, when the extremity E of the handle has arrived at *i*, the point *h* will be in *i*, and the point *g* in *f*, and the lever will be raised to the position A*a*. Thus it appears, that the motion of the power and the weight are always proportional. When a roller is fixed at E, a curve parallel to EO, or OF, must be drawn as formerly. (See Appendix to Ferguson's *Lectures*.)

CHAP. VI.—ON THE FIRST MOVERS OF MACHINERY.

On the First Movers of Machinery.

The powers which are generally employed as the first movers of machines are, water, wind, steam, and animal exertion.[1] The mode of employing water as an impelling power has already been given at great length in the article HYDRODYNAMICS. The application of wind to turn machinery will be discussed in the chapter on Wind-mills; and what regards steam will be more properly introduced into the article STEAM-ENGINE. At present, therefore, we shall only make a few remarks on the strength of men and horses; and conclude with a general view of the relative powers of the first movers of machinery. The following table contains the weight which a man is able to raise through a certain height in a certain time, according to different authors.

Number of Pounds raised.	Height to which the Weight is raised.	Time in which it is raised.	Duration of the Work.	Names of the Authors.
1000	180	60 minutes		Euler
60 (French.)	1 (French.)	1 second	8 hours	Bernoulli
25 (French.)	220 (French.)	145 seconds		Amontons
170 (French.)	1 (French.)	1 second	half an hour	Coulomb
1000	330	60 minutes		Desaguliers
1000	225	60 minutes		Smeaton
30	$3\frac{1}{2}$	1 second	10 hours	Emerson
26 or 30	2·45 feet	1 second		Schulze

According to Amontons, a man weighing 133 pounds French ascended sixty-two feet French, by steps, in thirty-four seconds, but was completely exhausted. The same author informs us that a sawer made 200 strokes of eighteen inches French each, with a force of twenty-five pounds, in 145 seconds; but that he could not have continued the exertion above three minutes.

It appears from the observations of Desaguliers, that an ordinary man can, for the space of ten hours, turn a winch with a force of thirty pounds, and with a velocity of two feet and a half per second; and that two men working at a windlass with handles at right angles to each other can raise seventy pounds more easily than one man can raise thirty. The reason of this is, that when there is only one man, he exerts variable efforts at different positions of the handle, and therefore the motion of the windlass is irregular; whereas, in the case of two men, with handles at right angles, the effect of the one man is greatest when the effect of the other is least, and therefore the motion of the machine is more uniform, and will perform more work. Desaguliers also found, that a man may exert a force of eighty pounds with a fly when the motion is pretty quick; and that, by means of a good common pump, he may raise a hogshead of water ten feet high in a minute, and continue the exertion during a whole day.

According to Dr Robison, a feeble old man raised seven cubic feet of water, = 437·5 pounds avoirdupois, $11\frac{1}{2}$ feet high, in one minute, for eight or ten hours a day, by walking backwards and forwards on a lever; and a young man weighing 135 pounds, and carrying thirty pounds, raised $9\frac{1}{4}$ cubic feet of water, = 578·1 pounds avoirdupois, $11\frac{1}{2}$ feet high, for ten hours a day, without being fatigued.

From the experiments of Mr Buchanan, it appears that the forces exerted by a man pumping, acting at a winch, ringing, and rowing, are as the numbers 1742, 2856, 3883, and 4095.

The most interesting experiments on the strength of men were made by M. Coulomb; and as they are highly valuable, we shall endeavour to give a condensed account of them.

1. His first object was to ascertain the quantiy tof action which a man furnished while ascending a stair unloaded.

A man whose weight may be taken at seventy kilogrammes ascended the stairs of a dwelling-house at the rate of fourteen metres, provided he did not ascend more than twenty or thirty metres. His quantity of action is therefore 980 *kilogrammes raised one metre in one minute;* and if he continue at the work four hours, it will be 235,200 *kilogrammes raised one metre in four hours.*

The party of sailors who accompanied the Chevalier Borda to the top of the Peak of Teneriffe ascended 2923 metres in $7\frac{3}{4}$ hours. Hence their quantity of action in a day was 204,610 *kilogrammes raised one metre in* $7\frac{3}{4}$ *hours.*

Coulomb therefore considers 205 *kilogrammes raised one kilometre* as the quantity of action furnished by a man ascending a stair.

2. When a man, loaded with firewood, ascended a stair, his quantity of action was 109 *kilogrammes raised one kilometre.* Another man of unusual strength furnished 129 *kilogrammes through one kilometre;* but he had overexerted himself.

But even taking this extreme result, it follows *that the quantity of action of a man unloaded is to that when he is loaded as* 205 *to* 129, *or as* 16 *to* 10.

3. In order to determine the load which a man ought to

[1] The elastic power of heated air has been ingeniously employed as the first mover of machines by the Reverend Mr Stirling; and the still more intense power of liquefied carbonic acid has been tried, though unsuccessfully, by Mr Brunel; but our limits will not allow us to give any description of the mechanism by which these powers are applied. (See page 436, column second.)

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carry in order to produce a maximum *useful effect*, Coulomb remarks, that the only useful effect furnished by a man when loaded is the conveyance of the load. If his load was nothing, his actual quantity of action would be a maximum, but the useful effect would be nothing; and in like manner, if his load was 150 kilogrammes, he could scarcely move it, and the useful effect would also be nothing. Between 0 and 150 kilogrammes there will be some load by which the useful effect will be a maximum. Now, since a man unloaded raised 205 kilogrammes through one kilometre in a day, while a man loaded with 68 kilogrammes raised only 109 kilogrammes through one kilometre, it follows that 68 kilogrammes diminished his quantity of daily work 205 — 109 = 96 kilogrammes through one kilometre.

Let us now, as Coulomb has done, suppose the quantities of action lost proportional to the loads; then, calling P the load, and q the quantity of action lost, we shall have P : q = 68 : 96, and $q = P\frac{96}{68} = 1{\cdot}41\,P$, or 1·41 kilometres multiplied by P. Hence the quantity of action furnished under the load P will be $205 - 1{\cdot}41\,P$. If h is the height through which the man is able to ascend in a day with the load P, then Ph will be the useful effect of his work, and $(70 + P)\,h$ will be his total quantity of daily action, 70 kilogrammes being taken as his weight. Hence we obtain

$$(70 + P)\,h = 205 - 1{\cdot}41\,P, \text{ and, by reduction,}$$

$$Ph = P\frac{(205 - 1{\cdot}41\,P)}{70 + P}; \text{ or,}$$

making $a = 205$, $b = 1{\cdot}41$, and W = 70, we have

$$Ph = P\frac{(a - bP)}{W + P},$$

which will be a maximum when

$$P = W\left(\sqrt{1 + \frac{a}{bW}} - 1\right) = 0{\cdot}754\,W = 53 \text{ kilogrammes.}$$

If this value of P is now substituted in the formula,

$$Ph = P\frac{(205 - 1{\cdot}41\,P)}{70 + P},$$

we shall have Ph = 56 kilogrammes raised through 1 kilometre in a day as the measure of the useful effect of a man when carrying a load up a stair.

Hence this mode of employing the strength of a man consumes nearly $\frac{3}{4}$ths of his real action, his useful effect being only 56, while his total effect is 205; and, therefore, the expense of employing him will be *four* times more than that of a man who, having ascended the stair unloaded, raises a weight (by his own descent by gravity) through the height to which he ascended.

If we suppose the man to be so loaded as to perform no work, a case which happens when he bears the greatest weight he can carry, then $205 - 1{\cdot}41\,P = 0$, and P = 145 kilogrammes, which is the weight which an ordinary man can barely carry.

Hence, the formulæ of Coulomb above given correspond to the maximum of the total action of a man ascending a stair unloaded, to the *minimum* of action when he is loaded with a weight which he can barely carry, and to an *intermediate* quantity of action of 68 kilogrammes, the ordinary load with which a man can ascend stairs.

4. Sir David Brewster has greatly simplified the formulæ given by Coulomb, by considering, what Coulomb found to be nearly the case, that the quantity of useful effect is only $\frac{1}{3}$d of the total quantity of action, and making $1{\cdot}41 = 1\frac{1}{2}$.

By these substitutions the formula $Ph\frac{(a - bP)P}{W+P}$ becomes $Ph = \frac{(3W - 1\frac{1}{2}P)P}{W + P}$, and $h = \frac{3W - 1\frac{1}{2}P}{W + P}$, which becomes a maximum when $P = W(\sqrt{3} - 1) = 0{\cdot}732\,W$.

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When P = 2W, we obtain $3W - 1\frac{1}{2}P = 0$, and $h = 0$; from which it follows, that when P or the load is equal to 2W, or twice the weight of the man, or $= 2 \times 70 = 140$ kilogrammes, he loses the power of ascending.

When P = W, or when the load is equal to the weight of the man, the mean quantity of action will be reduced one half. This agrees with the observation made by Coulomb, that the reduction of action was in this case from 205 to 96 when the load was 68, the value of w being 70 kilogrammes.

5. The next case discussed by Coulomb is that of a man walking along a horizontal road either unloaded or loaded.

A man walking *unloaded* for several days in succession can accomplish easily 50 kilometres in a day, which gives a quantity of action equal to 3500 *kilogrammes carried* 1 *kilometre.*

Porters *loaded* with 58 kilogrammes of furniture had a quantity of action of 2048 *kilogrammes carried* 1 *kilometre.* Hence the quantity of action in these two cases, *without* and *with* a load of 58 kilogrammes, is as 7 to 4.

When the load was 44 kilogrammes, the quantity of action was 2166 kilogrammes carried 1 kilometre.

When the load is 58 kilogrammes, Coulomb assumes as the best measure of the quantity of action 2000 *kilogrammes carried* 1 *kilometre.*

But the quantity of action *lost* in carrying a load is 3500 — 2000 = 1500 *kilogrammes carried* 1 *kilometre;* and assuming as before that the losses q are proportional to the loads P, we shall have 58 : P = 1500 : q, and $q = P\frac{1500}{58} = 25{\cdot}86\,P$, and the real quantity of action will be $3500 - 25{\cdot}86\,P$; and making this equal to 0, we have P = 135·4 kilogrammes, which coincides nearly with 140, the result of our simplified formula, as the greatest load which a man can carry.

Hence Coulomb obtains his general formula in the following manner:—

Calling d the distance through which a man can carry the load P, and W the weight of the man, we have $(P + W)d$ for his quantity of action. Hence we obtain $(P + W)d = 3500 - 25{\cdot}86\,P$, and $Pd = \frac{(3500 - 25{\cdot}86\,P)P}{P + W}$; or,

making $3500 = a$, $25{\cdot}86 = b$, we have $Pd = \frac{(a - bP)P}{P+W}$, which becomes a maximum when $P = W\left(\sqrt{1 + \frac{a}{bW}} - 1\right)$, or P = 0·72 W.

Sir David Brewster has simplified these formulæ, and reduced them to the very same as those formerly given, by considering that $3500 = 50 \times 70$, that is, $a = 50\,W$, and by making the co-efficient of P 25 instead of 25·86. By such substitutions we have $Pd = \frac{(50\,W - 25\,P)P}{P + W}$, and $d = \frac{50\,W - 25\,P}{P + W}$, which becomes a maximum when P $= W(\sqrt{3} - 1) = 0{\cdot}732\,W$, the very same result as when the man ascended stairs.

When P = 2W, then $50\,W - 25\,P = 0$, and $d = 0$; which shows that when the load is equal to twice the weight of the man, he can no longer carry it through any distance. The following is a comparison of these results with one another and with those of Coulomb:

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Nature of the Work.	Values of P. Coulomb.	Brewster.
In ascending a height by stairs	0·754 W	0·732
In travelling along a horizontal road	0·72 W	0·732
Mean	0·737	0·732

6. Coulomb's next case is, when the porters return *unloaded to carry away a new load.*

If we call the distance which a man can travel unloaded D, and x the distance through which he travels unloaded during the day's work, then WD will be the quantity of action when he travels the whole day unloaded, and Wx a portion of his day's journey. Then $\frac{Wx}{WD} = \frac{x}{D}$ will be the portion of his day's work when he is unloaded, the whole day's work being unity; for $\frac{x}{D} = 1$ if $x = D$. But as the labourer walks over the same space x loaded, and as his daily action when carrying a load P is $3500 - 25{\cdot}86\ P$, the portion of his action under the load P will be $(P + W)x$, and the ratio of this quantity to the daily quantity of action, or $\frac{(P + W)x}{3500 - 25{\cdot}86\ P}$, will indicate the part of his daily labour which he furnishes under the load P. The sum of these two quantities, namely, when loaded and when unloaded, will be equal to the labour of the entire day, or $\frac{x}{D}$

$$+ \frac{(P + W)x}{3500 - 25{\cdot}86\ P} = 1.$$

But if we suppose D to be fifty kilometres, and W = 70 kilogrammes, as before, we have WD = 3500; then, calling $25{\cdot}86 = b$, we shall have, after reduction,

$$Px = \frac{(WD^2 - bDP)P}{2WD + (D - b)P},$$

which is the useful portion furnished by the man in one day.

Calling $WD^2 = a$, $bD = c$, $2WD = e$, and $D - b = f$, we obtain $Px = \frac{aP - cP^2}{e + fP}$, which becomes a maximum when $P = \frac{e}{f} + \left(\sqrt{1 + \frac{fa}{ce}} - 1\right)$ or $P = 61{\cdot}25$, and $P = 0{\cdot}9\ W$.

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The preceding formulæ have likewise been simplified by Sir David Brewster, by considering that WD = 50 W, that D = 50, and by taking $b = 25$ in place of 25·86, so that $b = \frac{1}{2}D$. By substituting these values, we obtain

$$Px = \frac{(2500\ W - 25D^2P)P}{\frac{1}{2}D(100\ W + P)},$$

which becomes a maximum when $P = 280\ (\sqrt{1\frac{1}{2}} - 1)$. Hence

$$P = 62{\cdot}928 \text{ kilogrammes, or} = 0{\cdot}8989\ W;$$

a load very nearly equal to that which porters are in the practice of carrying under similar circumstances.

If we substitute different values of P in Coulomb's formulæ from 58 to 65, we shall find that Px, the maximum of useful effect, varies from 690 to 691, which shows that a variation of several kilogrammes in the load occasions a very trifling change in the useful effect.

From a comparison of the preceding results, it follows that the quantity of action of a man travelling unloaded is to that when he travels loaded, under the circumstances of the present case, as 505 to 100, or as 5 to 1 nearly.

Coulomb has made a very interesting comparison of the quantity of fatigue undergone by a man ascending a stair and travelling along a horizontal road. The quantity of action in these two cases has been shown to be as 205 to 3500, or 1 to 17. Now, the ordinary height of a step is about 135 millimetres, or $5\frac{2}{3}$ English inches, and its width thrice as great, or about $16\frac{1}{2}$ English inches. Hence $17 \times 135 = 2295$ millimetres, is the length of a horizontal road on which the man can walk with the same fatigue as in ascending 135 millimetres. But the force of a man is 650 millimetres, or twenty-six inches, consequently the man experiences the same fatigue in ascending 135 millimetres ($5\frac{2}{3}$ inches) as in advancing horizontally three paces and a half, or *seven feet seven inches English measure.*

The following table exhibits the preceding results in a condensed form.

Table of the Quantity of Daily Action of a Man when exerting himself in different ways.

Nature of the Motion.	Nature of the Work.	Nature of the Ground.	Mechanical Effect. Kilogrammes.	
1. Walking	Unloaded	Level	2500	raised 1 kilometre.
2. Walking	Loaded with 58 kilog., and returning unloaded for another burden. The *useful effect* is	Level	692·4	1 do.
3. Walking	Always loaded	Level	912	1 do.
4. Walking	With a loaded wheel-barrow. The *useful effect* is	Level	1022·7	1 do.
5. Walking up a stair	Unloaded. The *mechanical effect* is		205	1 do.
6. Standing	Raising a weight to drive piles. The *useful effect* is		75·2	1 do.
7. Standing	Raising a weight to coin money		39·5	1 do.
8. Walking up a stair	Loaded with 58 kilogrammes. The *useful effect* is		56	1 do.
9. Standing	Raising water from a well by a double bucket. The *useful effect* is		71	1 do.
10. Standing	Pumping		190	1 do.
11. Standing	Turning a winch		116	1 do.
12. Standing	Reaping		259	1 do.
13. Standing	Rowing		273	1 do.
14. Digging with a spade			62·3	1 do.

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The following important results have been given by M. Hachette:—

	Mechanical Effect.	
1. A man walking up an inclined plane of 14 centimetres to 1 metre with a load of 7½ kilog., and himself weighing 70 kilog. and walking 7½ hours daily	Kilogrammes. 225	raised 1 kilom.
2. A man walking loaded in a mountainous country	140	1 do.
3. A porter carrying wood up a stair, including his weight[1]	112 to 120	1 do.
4. A porter carrying coals up a stair, his weight included	40	1 do.
5. A man raising a weight to drive piles[2]	48	1 do.
6. A man drawing a boat *a la bricole*	110	1 do.

In the following results, given also by M. Hachette, the numbers are dynamical units or cubic metres of water carried a metre on a horizontal road.

1. A soldier loaded with from 20 to 25 kilog. travelling 20 kilometres a day	1800 to 1900	raised 1 kilom.
2. A Roman soldier travelling 40 kilometres a day by forced marches	4400 to 4800	1 do.
3. Hawker with crotchets, his weight not included	792 to 880	1 do.
4. Porters drawing a 4-wheel waggon over unequal ground[3]	626	1 do.
5. Do. on horizontal planks	900 to 1000	1 do.
6. Ditto on the ground, with superficial inequalities	600	1 do.
7. A man drawing a boat in a canal, or 50,000 kilog. transported 11 kilometres	550,000	1 do.

Among the various ways of applying the strength of men to produce great mechanical effects, the following method of weighing anchors, used by the natives of the coast of Coromandel, is extremely interesting and instructive. It was communicated to the writer of this article many years ago, by a celebrated naval officer, who himself witnessed the process of raising the anchor of his majesty's ship Minden, in September 1814.

The natives, who had been permitted by Sir Samuel Hood to show their method of weighing anchors, formed a raft about three or four feet in diameter, by lashing together, in the form of a rude cylinder, a number of spars, such as top-masts, jib-booms, &c. The buoy-rope of the anchor was wound round the middle of this, and made fast. Thirty small ropes having been fixed to the raft, were coiled round it several times in an opposite way to the buoy rope, so as to form "slew-ropes," or turning ropes. Sixty natives then got upon the spar, and pulled by the ropes so as to turn the raft of spars round. The buoy-rope soon became tight, and any farther rotation of the spar was prevented. The natives now held the slew-ropes tight and firm in both hands, and, standing erect and in a line on the top of the spar, the whole sixty, at the word of command, threw themselves suddenly backwards, so that they all fell flat on the surface of the water at the same instant. By this act the raft of spars turned round one quarter of a circle from the vertical to the horizontal position of the men. This operation did not, of course, start the anchor, but it tightened the buoy-rope to such a degree as to require considerable force to prevent the raft from turning back again. The next turn was made by alternate pairs of the men keeping their horizontal position on the water, while the intermediate pairs climbed up by means of their slew-ropes to the top of the raft. When there, they again tightened their ropes, threw themselves on their backs as before, and then turned the raft another quarter of a circle, the other men "taking in the slack," or tightening their slew-ropes, during the operation. The same operation was repeated by the other half of the party, till the anchor was fairly lifted off the ground. All the natives then continued stretched on the water till the boats towed the raft and the anchor into deep water, when it was hove in the usual way. The anchor was three tons in weight.

When the anchor is lifted off the ground the raft has a tendency to turn back again. This actually took place, in consequence of some of the natives getting tired and letting go their hold; and the rest not being able to overcome the additional load thus suddenly thrown upon them, the anchor sunk to the bottom, and gave such a rapid whirl to the raft, that some of the natives were actually carried round along with it. This might be prevented, as our correspondent suggests, by having *two* buoy-ropes in place of one, and coiling them round the raft in *opposite directions*, the rope that slackens or uncoils itself by each quarter turn of the raft being again tightened. This too would allow the whole strength of the party, in place of half of it, to be employed in the operation. A water windlass, to be worked by men in boats, might, as the narrator suggests, be contrived so as to be used when amphibious workmen, such as those of the coast of Coromandel, cannot be had.

In the above process the cylindrical raft is the axle, the men the handspikes, and their weight the moving power. The less the diameter of the spar round which the rope coils, the greater is the power; and the greater the diameter of the part upon which the men stand, the larger is the lever by which they act. The raft should therefore be constructed to give this advantage; and there might be two cylinders of different diameters for the two buoy-ropes, upon the principle of the wheel and axle, shown in fig. 27.

The strength of men varies with the climate and the food. Coulomb found that the grenadier performed one third more work than the other companies. "I have executed," he says, "great works at Martinique by the troops when the thermometer rarely stood below 68° of Fahrenheit, and I have executed in France the same kind of work by troops; and I am assured that under the 14th degree of latitude, where the men are almost always inundated by perspiration, *they* are not capable of *one half the quantity of daily work* which they can furnish in our climate." The following measures of the strength of different races of men were made by M. Peron, with Regnier's dynamometer.

England	71·4
France	69·2
Timor	58·7
Van Diemen's Land	51·8
New Holland	50·6
Average strength	60·34

[1] This case is No. 6 of Coulomb's table, where the porter's weight was not included.

[2] This result was obtained by M. Lamande, from the work of thirty-eight men, who raised by a pulley a weight of 587 kilog. to drive piles.

[3] Guinevau, *Essai sur les Machines*, p. 271. The ground was often clayey.

On the Strength of Horses, &c.

On the Strength of Horses, &c.

Very few accurate observations have been made on the quantity of work done by different quadrupeds, and it would therefore be desirable if the subject were taken up in reference to the different breeds of horses, and the various purposes for which they are employed.

The following table contains several accurate results collected by M. Hachette. The daily action is measured by the draught and the distance travelled over, and the useful effect is measured in dynamical units, each of which is the weight of a cubic metre of water carried a metre upon a horizontal road.

	Kilog.		Kilom.	Daily action.	Useful Effect Dyn. Units.
1. A cart-horse,	140	×	40	= 5000	
2. A post-horse,	90	×	38	= 3420	
3. A horse moving in a circle, and working a pump.....					585
4. A horse raising plaster, 12 hours daily.....				1684	842
5. A horse working at a pump. Mean of *three* horses.....				1185	595
6. A horse raising water by a pump. Mean of *eight* horses,				2948	675
7. A horse raising coals. Mean of two horses. *Doubtful*.....					780
8. A horse drawing a load of 150,000 kilogrammes eight kilometres.....					800
9. The force of a horse acting 24 hours is equal to.....					5974 dyn. units.

The comparative strength of horses and men has been variously given by different authors, and the discrepancy is so great as to render more necessary the experimental inquiry which we have above recommended. The following table will justify this observation:

One horse is equal to 14 men. Schulze.
One horse is equal to 7 men. Bossut.
One horse is equal to 5 men. Desaguliers and Smeaton.
One ass is equal to 2 men. Bossut.

The following results have been given by Desaguliers.

One horse can draw 200 pounds two and a half miles per hour for eight hours a day. If the load is 240 pounds, he can work only six hours.

One horse can draw from 450 to 750 pounds up a steep hill, which is more than *three* men can carry up it.

One powerful horse can draw 2000 pounds up a short and steep hill.

One horse has been known to carry 650 or 700 pounds for seven or eight miles without a rest, and to continue this as its ordinary work.

One horse carried 1232 pounds, or eleven hundredweight, of iron, for eight miles.

In these, as well as in the following results taken from different authors, nothing is said of the nature of the road, which is an essential element in the consideration of this subject.

Two horses, according to Amontons, when ploughing, can exert a force of 150 pounds, or seventy-five pounds each.

One horse, according to Smeaton, can raise 250 hogsheads of water in an hour by means of pumps.

One horse, according to Mr Fenwick, can raise 1000 pounds avoirdupois thirteen feet per minute for twelve hours, the horse moving about two miles an hour, by means of a wheel and axle.

One horse, according to Mr Fenwick, can exert a force of seventy-five pounds, moving thirteen feet per minute, and for nine and a half hours.

On the Strength of Horses, &c.

Four horses, according to Regnier, had a mean draught of thirty-six myriogrammes in 794 hours.

One *mule*, according to Cazand, can, in the West Indies, exert a force of 150 pounds, walking three feet in a second, and working two hours out of about eighteen.

One horse is supposed to be able to drive 1000 spindles with preparation of cotton water-twist, 1000 spindles with preparation of cotton mule yarn, and seventy-five spindles with preparation of flax yarn.

One horse can draw 140 pounds with the velocity of 200 feet per minute.

The force of a horse has been estimated as follows:

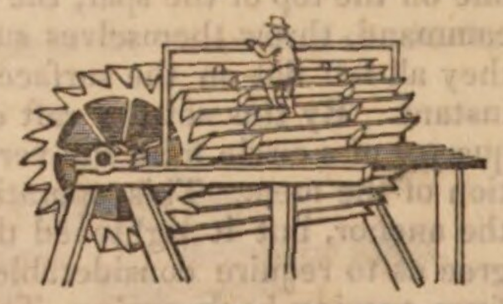
Useful Mechanical Effect.	
44,000	pounds raised one foot in one minute. Desaguliers.
29,916	pounds raised one foot in one minute. Smeaton.
33,000	pounds raised one foot in one minute. Watt.

Methods of applying the Power of Men and Horses to drive Machinery.

The methods of applying the power of men and horses to drive ordinary machines is so familiar to every person, that it would be unprofitable to give any particular description of it. Nothing is more familiar to us than a man working at a pump, either by a lever or by a winch turning an axle, or driving round a vertical axis by a lever, and continually walking in a circle. The application of one or more horses to a thrashing-mill, where the horses walk round in a circle, yoked to the extremities of levers which drive a vertical axis, is equally familiar. There are some methods, however, of applying animal power, which, though now little used, are historically interesting, and may in some cases be still resorted to with advantage.

The simplest of these is the *tread-mill* or *tread-wheel*, which has within the last twenty years become common in our jails and bridewells, as an instrument of punishment as well as of useful labour. It is shown in the annexed figure, where one or more men are seen climbing as it were up steps on the circumference of a large wheel, whose axis is thus put in motion. The men hold by a fixed rail, and as their weight presses down the step upon which they tread, they ascend the next step, and thus drive the wheel. The muscular force used by the men re-acts principally on the horizontal bar on which they rest, and therefore their weight is the principal source of the moving force.

Fig. 133.



Another method of applying the force of a man is shown in fig. 134, where the man climbing on a rope employs both his weight and his muscular force in turning round the pulleys round which the rope passes. The re-action of his muscular force is certainly in this case borne by the machine, as Professor Moseley remarks; but notwithstanding this, we cannot agree with him in the conclusion, that it "appears to possess great advantages over the *tread-wheel*, in the economy of force, space, and materials." In the first place, the weight of the man does not act vertically, and a considerable part of it is injuriously employed in bending the rope and increasing the friction, by pressing it against the rims of the pulley. The friction of two axles is also a disadvantage, and even though the mechanical force of the man were greater during a short time than on the tread-wheel,

Fig. 134.

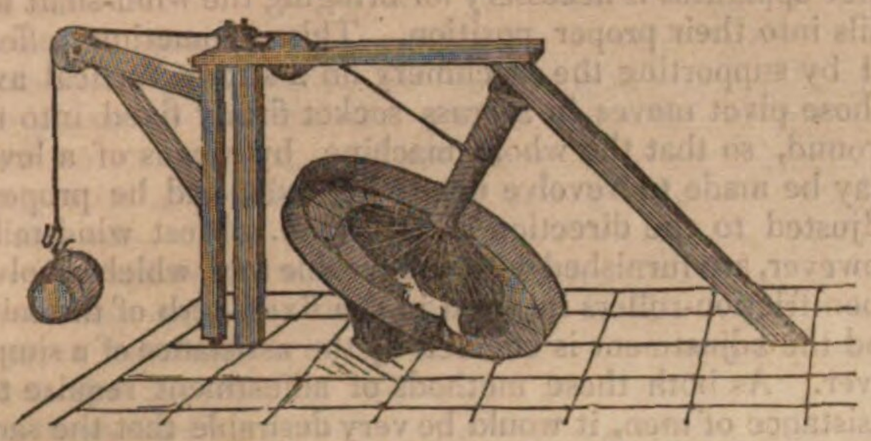
On the Strength of Horses, &c.

we are quite convinced that his daily labour would be less, from his experiencing more fatigue in the one case than the other.

A very excellent way of employing the power of a man, is to make him ascend steps on the inside of a large vertical wheel, a method which we saw in action not many years ago in London, where the force of the man was thus employed to work a crane.

An ancient method of employing horses or oxen to work a crane is shown in the annexed figure, where the animal constantly ascends the inclined plane of a wheel placed obliquely to the horizon, and drives it by the action of its feet against low steps of wood crossing its path.

Fig. 135.



Another method is shown in fig. 136, where a horse tied to a post has its hind feet resting on low steps on the outside of a wheel, while its fore feet rest upon a fixed plank beside the post. In this case, both the weight of the horse and the muscular force of its legs are combined in giving a rotatory motion to the wheel or cylinder.

Fig. 136.

It is a remarkable fact, that so recently as November 1830, Mr Bramley and Lieutenant Parker took out a patent for various contrivances for applying the power of men and horses to impel carriages on railways. Their first plan is to place a horse upon two tread-wheels or drivers, having raised edges or ribs on their circumferences, against which the fore and hind feet of the horse are intended to press when in the act of stepping, in order to make the wheels revolve by the weight of his body, and by trains of toothed wheels to the running wheels of the carriage. The horse being harnessed to the sides of the frame in which the wheels are mounted, it is intended that he shall impel the wheel also by his muscular power.

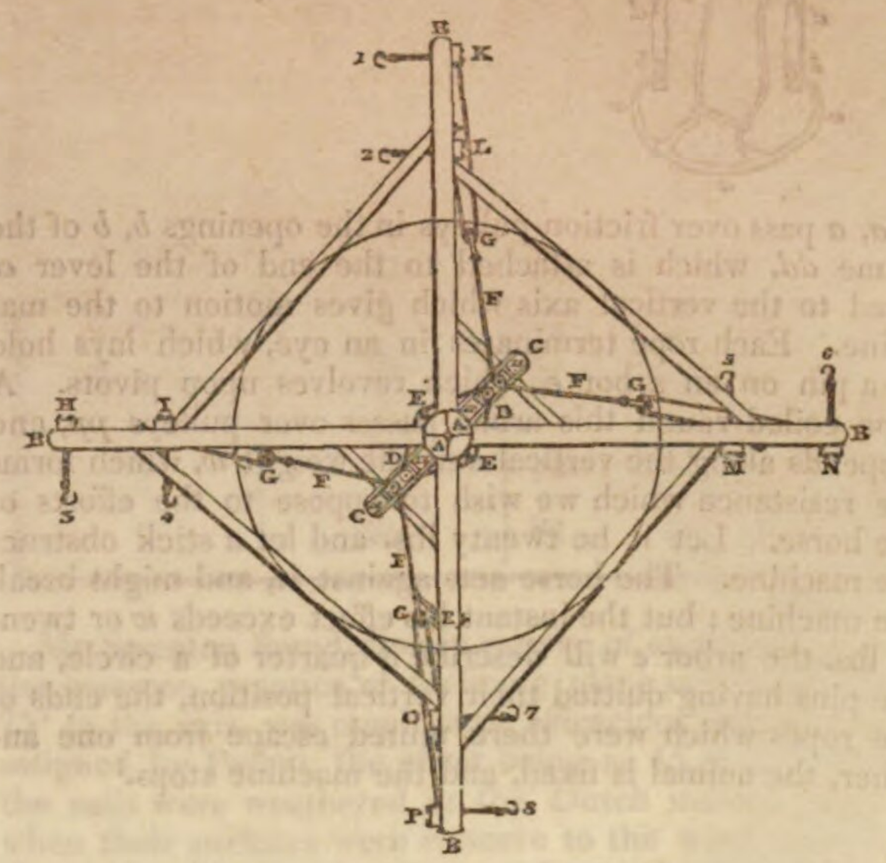
The next contrivance is more novel and grotesque, and even if it had more merit than it has, we should be ashamed to see our fellow-creatures lying prostrate on the ground to perform the functions of the beasts that perish. In order to impel a railway carriage, a man is placed in a horizontal position in the carriage, supported by his body bearing upon a rest. His feet are connected to stirrups, and his legs being put in motion, as in the act of swimming, he communicates a reciprocating motion, which, by the intervention of rods and cranks, turns the running wheels. But while our unfortunate friend is labouring with his feet, some occupation is found also for his head, and he is entrusted with the duty of directing with his hands the steering apparatus in front.

A third plan of these gentlemen is to unite with the horizontal man a perpendicular one, who is to aid his neighbour by stepping upon treadles connected by rods and cranks with the running wheels. Such contrivances might sometimes be useful as supplementary ones, when the moving power fails; and the passengers might in turn assist in driving the carriage to its destination.

On the Strength of Horses, &c.

When horses are yoked in thrashing-mills, they generally pull with unequal force, and too much work is done by those which are best disposed for their work. A very ingenious contrivance for regulating the action of horses under these circumstances, was invented by Mr Walter Samuel, blacksmith at Niddry, in Linlithgowshire, and is now in actual use in many parts of Scotland. In the annexed figure, it is represented as applied to *four* horses,

Fig. 137.



but it may readily be applied to any other number. The figure is a plan of the vertical axis AA of the thrashing-mill, and the levers B, B, &c. by which that axis is driven, and supporting the great wheel which drives the horizontal axis that enters the mill. Upon two frames C, C, fixed to A, and supported on the arms B, B, are fixed two pulley-blocks with running sheaves, which shift either inward to the axis or outward from it. Over these sheaves, at the ends 12 and 13, passes an endless rope or chain DEDE, which also goes over two sheaves E, F, to keep the rope or chain clear of the revolving axle A.

Two ropes FF, FF, pass over the sheaves 11 and 14, and to each end of them is fastened a block C with running sheaves, over which pass the double ropes GLK1 and G2, which the horses pull when driving the machine, the ropes for each horse being fastened to hooks 1, 2; 3, 4; 5, 6; 7, 8; after passing through running sheaves in the limbers H, I; K, L; M, N; and O, P.

By this mechanism, any tendency of the horses to pull inwards or outwards is corrected, and the strain of the draught presses fairly on their shoulders; an advantage which, in the ordinary way of yoking horses, cannot be obtained without a particular contrivance.

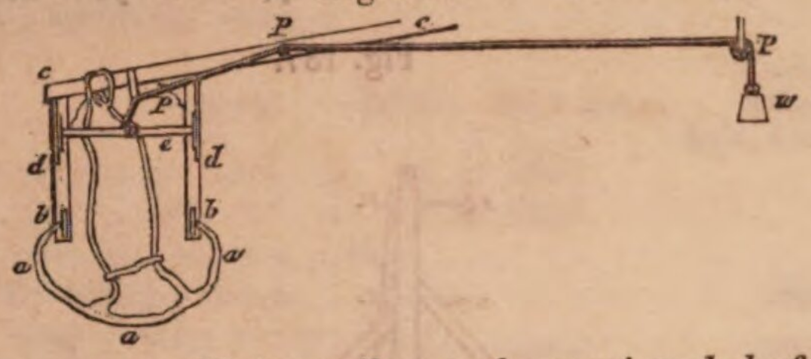
As all the horses, when yoked, are now connected together, it will be seen, that when any one horse relaxes from his labour, the action of the other horses will instantly press the collar to his shoulders, and excite him to exertion. If the horse at 1, 2, for example, relaxes, the one at 5, 6 would instantly take up his rope, and either cause the horse 1, 2 to exert himself, or be pulled backwards. The same thing would happen with any or all of the other horses, so that all of them are as it were united into one power driving the machine. If it is necessary to take out

On the Construction of Wind-Mills.

one horse, as that at 7, 8, an iron hook upon the rope F is hooked into the eye of a bolt fastened to the arm, as at R.

Another contrivance connected with the draught of horses deserves a place in this chapter. It is an invention of Baron de Prony for unyoking horses, to prevent them from injuring the machine when its motion is accidentally obstructed. It may also be employed for limiting the efforts of horses thus employed. In the annexed figure, ropes

Fig. 138.



a, *a*, *a* pass over friction-pulleys in the openings *b*, *b* of the frame *dd*, which is attached to the end of the lever *cc* fixed to the vertical axis which gives motion to the machine. Each rope terminates in an eye, which lays hold of a pin on an arbor *e*, which revolves upon pivots. A rope coiled round this arbor passes over pulleys *pp*, and suspends along the vertical axis the weight *w*, which forms the resistance which we wish to oppose to the efforts of the horse. Let it be twenty lbs. and let a stick obstruct the machine. The horse acts against it, and might break the machine; but the instant his effect exceeds *w* or twenty lbs. the arbor *e* will describe a quarter of a circle, and the pins having quitted their vertical position, the ends of the ropes which were there united escape from one another, the animal is fixed, and the machine stops.[1]

CHAP. VII.—ON THE CONSTRUCTION OF WIND-MILLS.

A wind-mill is represented in fig. 139, where MN is the circular building that contains the machinery, E the extremity of the wind-shaft or principal axis, which is generally inclined from 8 to 15 degrees to the horizon; and EA, EB,

Fig. 139.

EC, ED, EF five rectangular frames, upon which sails of cloth of the same form are stretched. At the lower extremity G of the sails their surface is inclined to the axis 72°; and at their farthest extremities A, D, &c. the inclination of the sail is about 83°. Now, when the sails are adjusted to the wind, which happens when the wind blows in the direction of the wind-shaft E, the impulse of the wind upon the oblique sails may be resolved into two forces, one of which acts at right angles to the wind-shaft, and is therefore employed solely in giving a motion of rotation to the sails, and the axis upon which they are fixed. When the mill is used for grinding corn, a crown-wheel, fixed to the principal axis E, gives motion to a lantern or trundle, whose axis carries the moveable millstone.

On the Construction of Wind-Mills.

Methods of turning the sails to the wind.

That the wind may act with the greatest efficacy upon the sails, the wind-shaft must have the same direction as the wind. But as this direction is perpetually changing, some apparatus is necessary for bringing the wind-shaft and sails into their proper position. This is sometimes effected by supporting the machinery on a strong vertical axis, whose pivot moves in a brass socket firmly fixed into the ground, so that the whole machine, by means of a lever, may be made to revolve upon this axis, and be properly adjusted to the direction of the wind. Most wind-mills, however, are furnished with a moveable roof, which revolves upon friction-rollers inserted in the fixed kerb of the mill; and the adjustment is effected by the assistance of a simple lever. As both these methods of adjustment require the assistance of men, it would be very desirable that the same effect should be produced solely by the action of the wind. This may be done by fixing a large wooden vane or weather-cock at the extremity of a long horizontal arm which lies in the same vertical plane with the wind-shaft. By this means, when the surface of the vane, and its distance from the centre of motion, are sufficiently great, a very gentle breeze will exert a sufficient force upon the vane to turn the machinery, and will always bring the sails and wind-shaft to their proper position. This weather-cock, it is evident, may be applied either to machines which have a moveable roof, or which revolve upon a vertical arbor.

On the Form and Position of Wind-mill Sails.

From an examination of more than fifty wind-mills in the vicinity of Lille, Coulomb has furnished us with the dimensions of the sails of the best Dutch mills. As these mills performed nearly the same amount of work when the velocity of the wind was about 19 feet per second, although there were slight differences in the arrangement of their sails, as well as in the inclination of their wind-shafts, Coulomb concluded that they were so constructed as to produce nearly a maximum effect.

In these mills the distance of the extremities of two opposite sails was sixty-six feet. The form of the sails was that of a rectangle, and their width was six feet, five feet of which was covered with cloth stretched on a frame, the remaining foot being a light board. The sail commenced 6 feet from the wind-shaft, so that the length AG was $\frac{bb}{2} - 6 = 27$ feet. The junction of the board with the cloth formed, on the side which faces the wind, a curve perceptibly concave at the commencement of the sail, and the curvature gradually diminished towards the extremity, where it vanished. Although every line of the surface of the cloth is curved, yet we may consider the surface of the sail as consisting of straight lines having different inclinations to the plane of the sail's motion. The inclination of these lines to this plane is called the *angle of weather;* and in Dutch sails this

[1] See *Annales des Arts*, tom. xix. p. 190.

On the Construction of Wind-Mills.

angle is 30° at the commencement G of the sail, diminishing gradually to the extremity D, where in some cases it is 12°, and in others 6°; the inclination of the wind-shaft varying from 8° to 15°.

The inclination assigned by Parent erroneous.

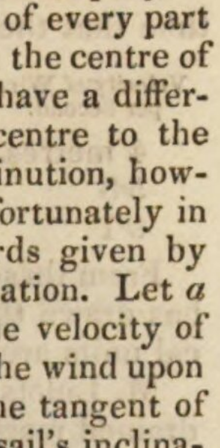
It appears from the investigations of Parent and Belidor, that a maximum effect will be produced when the sails are inclined 54° 44′ 13″ to the axis of rotation, or when the angle of weather is 35° 15′ 47″. In obtaining this conclusion, however, M. Parent has assumed data which are inadmissible, and has neglected several circumstances which must materially affect the result of his investigations. The angle of inclination assigned by Parent is certainly the most efficacious for giving motion to the sails from a state of rest, and for preventing them from stopping when in motion; but he has not considered that the action of the wind upon a sail at rest is different from its action upon a sail in motion; for, since the extremities of the sail move with greater rapidity than the parts nearer the centre (in the Dutch mills as 33 to 6), the angle of weather should be greater towards the centre than at the extremity, and should vary with the velocity of each part of the sail. The reason of this is very obvious. It has been demonstrated by Bossut, and established by experience, that when any fluid acts upon a plain surface, the force of impulsion is always exerted most advantageously when the impelled surface is in a state of rest, and that this force diminishes as the velocity of the surface increases. Now, let us suppose, with Parent and Belidor, that the most advantageous angle of weather for the sails of windmills is $35\frac{1}{4}°$ for that part of the sail which is nearest the centre of rotation, and that the sail has everywhere this angle of weather; then, since the extremity of the sail moves with the greatest velocity, it will in a manner withdraw itself from the action of the wind, or, to speak more properly, it will not receive the impulse of the wind so advantageously as those parts of the sail which have a less degree of velocity. In order, therefore, to counteract this diminution of force, we must make the wind act more perpendicularly upon the sail, by diminishing its obliquity or its angle of weather. But since the velocity of every part of the sail is proportional to its distance from the centre of motion, every elementary portion of it must have a different angle of weather diminishing from the centre to the extremity of the sail. The law or rate of diminution, however, is still to be discovered, and we are fortunately in possession of a theorem of Euler's, afterwards given by Maclaurin, which determines this law of variation. Let a represent the velocity of the wind, and c the velocity of any given part of the sail; then the effort of the wind upon that part of the sail will be greatest when the tangent of the angle of the wind's incidence, or of the sail's inclination to the axis, is to radius, as $\sqrt{2+\frac{9cc}{4aa}}+\frac{3c}{2a}$ to 1.

Euler's theorem.

Explanation and application of this theorem.

In order to apply this theorem, let us suppose that the radius or whip ED of the sail $\alpha\beta\delta\gamma$, is divided into six equal parts; that the point n is equidistant from E and D, and is the point of the sail which has the same velocity as the wind; then, in the preceding theorem, we shall have $c = a$ when the sail is loaded to a maximum; and therefore the tangent of the angle which the surface of the sail at n makes with the axis when $a = 1$, will be $\sqrt{2+\frac{9}{4}}+\frac{3}{2} = 3{\cdot}561 =$ tangent of 74° 19′, which gives 15° 41′ for the angle of weather at the point n. Since, at $\frac{1}{2}$ of the radius $c = a$, and since c is proportional to the distance of the corresponding part of the sail from the centre, we will have, at

Fig. 140.



$\frac{1}{6}$ of the radius, $c = \frac{a}{3}$; at $\frac{2}{6}$ of the radius, $c = \frac{2a}{3}$; at $\frac{4}{6}$, $c = \frac{4a}{3}$; at $\frac{5}{6}$, $c = \frac{5a}{3}$; and at the extremity of the radius, $c = 2a$. By substituting these different values of c instead of c in the theorem, and by making $a = 1$, the following table will be obtained, which exhibits the angles of inclination and weather which must be given to different parts of the sails.

On the Construction of Wind-Mills.

Parts of the Radius from the Centre of Motion at E.	Velocity of the Sail at these Distances, or Values of c.	Angle made with the Axis.		Angle of Weather.	
		Deg.	Min.	Deg.	Min.
$\frac{1}{6}$	$\frac{a}{3}$	63	26	26	34
$\frac{2}{6}$	$\frac{2a}{3}$	69	54	20	6
$\frac{3}{6}$ or $\frac{1}{2}$	a	74	19	15	4
$\frac{4}{6}$ or $\frac{2}{3}$	$\frac{4a}{3}$	77	20	12	40
$\frac{5}{6}$	$\frac{5a}{3}$	79	27	10	33
1	$2a$	81	0	9	0

Results of Smeaton's experiments.

Mr Smeaton found, from a variety of experiments, that the common practice of inclining plane sails from 72° to 75° to the axis, was much more efficacious than the angle assigned by Parent, the effect being as 45 to 31. When the sails were weathered in the Dutch manner, that is, when their surfaces were concave to the wind, and when the angle of inclination increased towards their extremities, they produced a greater effect than when they were weathered either in the common way, or according to Euler's theorem. But when the sails were enlarged at their extremities, as represented at $\alpha\beta$ in fig. 140, so that $\alpha\beta$ was one third of the radius ED, and αD to Dβ as 5 to 3, their power was greatest of all, though the surface acted upon by the wind remained the same. If the sails be farther enlarged, the effect is not increased in proportion to the surface; and besides, when the quantity of cloth is great, the machine is much exposed to injury by sudden squalls of wind. In Mr Smeaton's experiments, the angle of weather varied with the distance from the axis; and it appeared from several trials, that the most efficacious angles were those in the following table.

Parts of the Radius ED, which is divided into six parts.	Angle with the Axis.	Angle of Weather.
1	72	18
2	71	19
3	72	18 middle.
4	74	16
5	$77\frac{1}{2}$	$12\frac{1}{2}$
6	83	7

If the radius ED of the sail be 30 feet, then the sail will commence at $\frac{1}{6}$ED, or 5 feet from the axis, where the angle of inclination will be 72°. At $\frac{2}{6}$ED, or 10 feet from the axis, the angle will be 71°, and so on.

It has been proposed by Euler and other writers to make the sails elliptical sectors, and to intercept the whole cy-

On the Construction of Wind-Mills.

linder of wind, whose circumference is ACBFD, fig. 139; but recent experiments have proved that a maximum effect is produced when the wind can escape between the sails.

On the Relative and Absolute Effects of Wind-Mill Sails.

Effect.

The following maxims, deduced by Smeaton from his experiments, contain the most accurate information upon this subject.

Relative effect of wind-mill sails, according to Smeaton.

Maxim 1. The velocity of wind-mill sails, whether unloaded or loaded, so as to produce a maximum effect, is nearly as the velocity of the wind, their shape and position being the same.

Maxim 2. The load at the maximum is nearly, but somewhat less than, as the square of the velocity of the wind, the shape and position of the sails being the same.

Maxim 3. The effects of the same sails at a maximum are nearly, but somewhat less than, as the cubes of the velocity of the wind.

Maxim 4. The load of the same sails at the maximum is nearly as the squares, and their effects as the cubes, of their number of turns in a given time.

Maxim 5. When sails are loaded so as to produce a maximum at a given velocity, and the velocity of the wind increases, the load continuing the same,—1*st*, the increase of effect, when the increase of the velocity of the wind is small, will be nearly as the squares of those velocities; 2*dly*, when the velocity of the wind is double, the effects will be nearly as $10 : 27\frac{1}{2}$; but, 3*dly*, when the velocities compared are more than double of that where the given load produces a maximum, the effects increase nearly in the simple ratio of the velocity of the wind.

Maxim 6. In sails where the figure and positions are similar, and the velocity of the wind the same, the number of turns in a given time will be reciprocally as the radius or length of the sail.

Maxim 7. The load at a maximum that sails of a similar figure and position will overcome at a given distance from the centre of motion, will be as the cube of the radius.

Maxim 8. The effects of sails of similar figure and position are as the square of the radius.

Maxim 9. The velocity of the extremities of Dutch sails, as well as of the enlarged sails, in all their usual positions when unloaded, or even loaded to a maximum, is considerably quicker than the velocity of the wind.

Absolute effect of wind-mills in making oil of rape-seed.

The following very important results were obtained by M. Coulomb, in examining the wind-mills at Lille, in the Netherlands. These mills were made for the manufacture of oil of rape-seed, and were constructed in the following manner: *Seven* stampers for bruising the seeds were raised by means of an arbor carrying 14 wipers. *Five* of the stampers were of oak, each from 20 to 22 feet long, and from 9 to 11 inches square; their lower ends were shod with iron, weighing from 50 to 60 lbs.; and each stamper weighed about 1020 lbs. The other *two* stampers were of the same length, but only from 6 to 7 inches square, and weighed about 500 lbs. each: their purpose was to lock and unlock the wedges used in expressing the oil. One of these *two* only acted at once, but the rest acted together.

Velocity of Wind in Feet per Second.	Revolutions of Sails per Minute.	Number of Stampers used.	Weight of Stampers in lbs.	Work done in Twenty-four Hours.
7	$5\frac{1}{2}$	No stampers raised.		No work done.
7	3	1	1020	Striking two blows each 18 inches high.

Velocity of Wind in Feet per Second.	Revolutions of Sails per Minute.	Number of Stampers used.	Weight of Stampers in lbs.	Work done in Twenty-four Hours.
13	$17\frac{1}{2}$	2 = 2040 lbs. 1 = 500	2540	200 lbs. of oil.
20*	13	5 = 5100 1 = 500	5600	$3\frac{1}{2}$ tons of oil.
28†	$17\frac{1}{2}$	5 = 5100 1 = 500	5600	5 tons of oil.

On the Construction of Wind-Mills.

By taking an average of the work performed during several years, Coulomb found that each wind-mill manufactured annually 400 tons of oil. About one sixth of the force communicated to the stampers he conceives to be absorbed by their blows and the action of the wipers, including friction. Hence he calculates that 100 kilogrammes or one ton of oil requires for its manufacture 12,500 dynamical units.

M. Halle at Lille found that a steam-engine of ten-horse power prepared in twenty-four hours 500 kilogrammes of oil, which gives fifty kilogrammes for each horse. But we have already seen that the power of a horse working twenty-four hours is equal to 5974 dynamical units. Hence

Kilog. Units. Kilog.
as $50 : 5974 = 100 : 11948$ units,

agreeing very nearly with 12,500, the result obtained by Coulomb.

By supposing three tons to be the average work of one mill during an average state of the wind, we have $\frac{400}{3} = 133$ for the number of days of twenty-four hours to which the whole wind of the year at Lille is equivalent, blowing at the rate of a little less than four metres per second.

Effects in grinding corn.

Coulomb likewise examined the effect of wind-mills in grinding corn.

The millstone performed *five* revolutions in the same time that the sails and vertical arbor performed *one*.

Velocity of Wind per Second.	Revolutions of the Sails in a Minute.	Ditto of the Millstone.	Work performed in Twenty-four Hours, or Flour ground.
4 metres.	The sails just began to turn.		
5·8	$11\frac{1}{2}$	$57\frac{1}{2}$	10,000 kilog.
9·1	22	110	21,600.‡

From these and various other experiments, M. Hachette has drawn the conclusion, that from 500 to 550 dynamical units are required to grind 100 kilogrammes of corn.

Effects in raising water or other weights.

M. Lulofs of Leyden examined a Dutch wind-mill that drained marshes, and which had four rectangular sails set at a weather of 17°. It raised 1500 cubic feet of water four feet high in a minute when the velocity of the wind was 30 feet per second.

Coulomb found that in the Dutch mills, whose dimensions are given in page 432, the effect was 1000 lbs. raised 218 feet in a minute when the wind blew 20 feet in a second. He computed also that the force lost by friction was 1000 lbs. raised $18\frac{1}{2}$ feet per minute; and that the force consumed by the action of the wipers on the stampers was equal to 1000 lbs. raised $16\frac{1}{2}$ feet in a minute. Hence it follows that the total force of the wind was equivalent to 1000 lbs. raised $218 + 16\frac{1}{2} + 18\frac{1}{2} = 253$ feet in a minute.

Both Smeaton and Coulomb have attempted to determine the ratio between the velocity of the wind and that

[1] One ton is equal to 100 kilogrammes.

* All the sails were carried, the wind blew uniformly, and the velocity seemed to be the best suited to the machine.

† An area of two inches was taken in at the extremity of each sail.

‡ In this experiment the mill carried all her sails; but the flour was heated considerably, and in such cases the millers change from time to time the kind of grain to be ground, to *refresh the mill*, as they term it.

On the Construction of Wind-Mills.

of the arbor or wind-shaft of the mill. Smeaton has given the following results from Dutch sails in their common position, when they had a radius of 50 feet.

Velocity of Wind per Hour.	Revolutions of the Arbor in a Minute.	Ratio of these two Velocities.
2 miles.	3	0·666 to 1
4	5	0·800 to 1
5	6	0·833 to 1

Coulomb's results, which are as follows, differ widely from those of Smeaton, though they are susceptible of explanation.

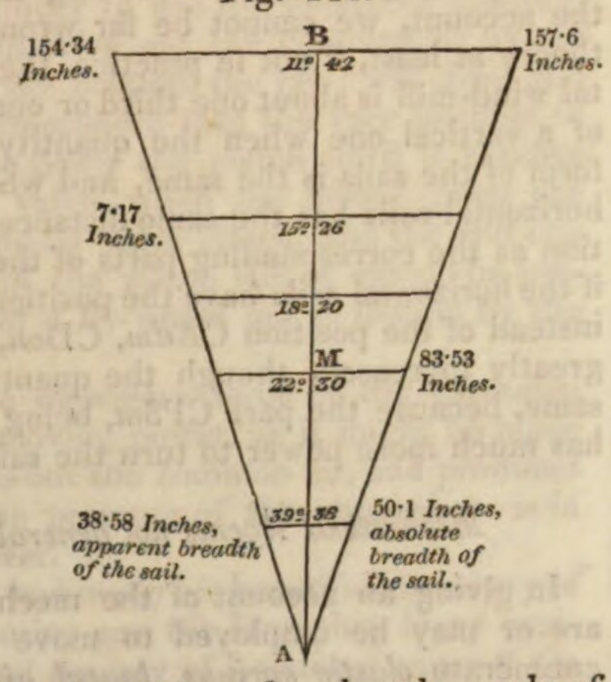
Velocity of Wind per Hour.	Velocity of the Wind per Second.	Revolutions of Arbor in a Minute.	Rates of these Velocities.
5·1 miles.	2·27 metres.	3	1·7 to 1
9·14	4·06	7½	1·22 to 1
14·6	6·5	13	1·05 to 1
20·4	9·1	17½	1·17 to 1
13·0	5·8	11½	1·13 to 1
20·4	9·1	22	0·93 to 1

In order to account for the discrepancies between these results and those of Smeaton, we may observe, that in the two first experiments, where the difference is the greatest, viz. 1·7 to 1, and 1·22 to 1, the mill was not doing its full work. The average of the ratios in the other four experiments, where the mill was doing full work, is 1·07, which is less different from Smeaton's results.

The principal cause of the discrepancy, however, is, that the ratio increases, as in all Smeaton's experiments, with the velocity of the wind; and as Smeaton's highest velocity was only five miles per hour, whereas the average velocity in the four last experiments of Coulomb was so high as 17·6 miles per hour, it is not difficult to understand how the ratios deduced from them should be so high.

A new mode of constructing the sails of wind-mills has been recently given by Mr Sutton, and fully described by Mr Hesleden of Barton, in a work exclusively devoted to the subject.

Fig. 141.



The limits of this article will not permit us to enter into any discussion respecting the principles upon which Mr Sutton's gravitated sails are constructed. It may be proper, however, to remark, that Mr Sutton gives his sails the form represented in fig. 141, and makes the angle of weather at the point M, equidistant from A and B, equal to 22° 30′. The inclination of the sail at any other point N of the sail, is an angle whose sine is the distance of that point from the centre of motion A, the radius being the breadth of the sail at that point. Fig. 141 shows the angles at the different points of the sail, and the apparent and absolute breadths of the sail at these points. Mr Sutton's mode of regulating the velocity of the sails, and of bringing them into a state of rest, is particularly ingenious.

ON HORIZONTAL WIND-MILLS.

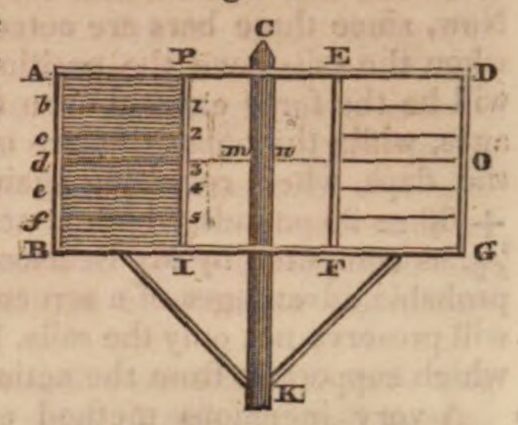
Horizontal wind-mills.

Various opinions have been entertained respecting the relative advantages of horizontal and vertical wind-mills. Mr Smeaton, with great justice, gives a decided preference to the latter; but when he asserts that horizontal wind-mills have only $\frac{1}{8}$ or $\frac{1}{10}$ of the power of vertical ones, he certainly forms too low an estimate of their power. Mr Beatson, on the contrary, who has received a patent for the construction of a new horizontal windmill, seems to be prejudiced in their favour, and greatly exaggerates their comparative value. From an impartial investigation, it will probably appear that the truth lies between these two opposite opinions; but before entering on this discussion, we must first consider the nature and form of horizontal wind-mills.

On the Construction of Wind-Mills.

In fig. 142 CK is the wind-shaft, which moves upon pivots. Four cross bars, CA, CD, IB, FG, are fixed to this arbor, which carry the frames APIB, DEFG. The sails AI, EG, are stretched upon these frames, and are carried round the axis CK, by the perpendicular impulse of the wind. Upon the axis CK a toothed wheel is fixed, which gives motion to the particular machinery that is employed. In the figure only two sails are represented; but there are always other two placed at right angles to these. Now, let the sails be exposed to the wind, and it will be evident that no motion will ensue; for the force of the wind upon the sail AI, is counteracted by an equal and opposite force upon the sail EG. In order, then, that the wind may communicate motion to the machine, the force upon the returning sail EG must either be removed by screening it from the wind, or diminished by making it present a less surface when returning against the wind. The first of these methods is adopted in Tartary, and in some provinces of Spain; but is objected to by Mr Beatson, from the inconvenience and expense of the machinery and attendance requisite for turning the screens into their proper positions. Notwithstanding this objection, however, we are disposed to think that this is the best method of diminishing the action of the wind upon the returning sails, for the moveable screen may be easily made to follow the direction of the wind, and assume its proper position, by means of a large wooden weathercock, without the aid either of men or machinery It is true, indeed, that the resistance of the air in the returning sails is not completely removed; but it is at least as much diminished as it can be by any method hitherto proposed. Besides, when this plan is resorted to, there is no occasion for any moveable flaps and hinges, which must add greatly to the expense of every other method.

Fig. 142.



Common method of bringing back the sails against the wind.

The mode of bringing the sails back against the wind, which Mr Beatson invented, is, perhaps, the simplest and best of the kind. He makes each sail AI to consist of six or eight flaps or vanes, AP*b*1, *b*1*c*2, &c. moving upon hinges represented by the dark lines AP, *b*1, *c*2, &c. so that the lower side *b*1, of the first flap overlaps the hinge or higher side of the second flap, and so on. When the wind, therefore, acts upon the sail AI, each flap will press upon the hinge of the one immediately below it, and the whole surface of the sail will be exposed to its action. But when the sail AI returns against the wind, the flaps will revolve round upon their hinges, and present only their edges to the wind, as is represented at EG, so that the resistance occasioned by the return of the sail must be greatly diminished, and the motion will be continued by the great superiority of force exerted upon the sails in the position AI. In computing the force of the wind upon the sail AI, and the resistance opposed to it by the edges of the flaps in EG, Mr Beatson finds, that when the pressure upon the former is 1872 pounds, the resistance opposed by the latter is only about thirty-six pounds, or $\frac{1}{52}$ part of the

Beatson's method.

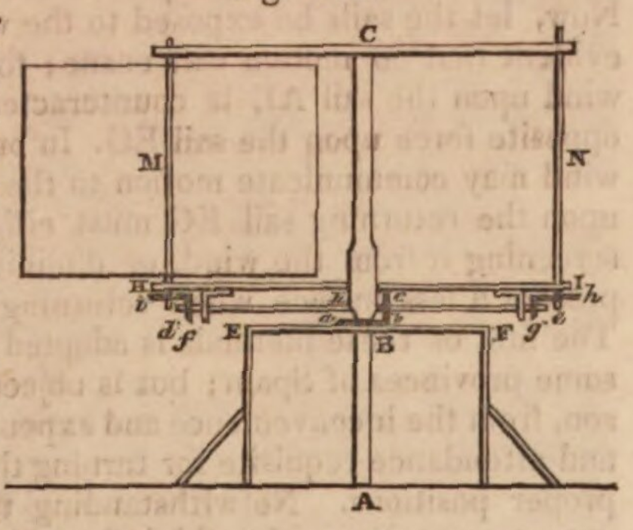
On the Construction of Wind-Mills.

whole force; but he neglects the action of the wind upon the arms CA, &c. and the frames which carry the sails, because they expose the same surface in the position AI, as in the position EG. This omission, however, has a tendency to mislead us in the present case, as we shall now see; for we ought to compare the whole force exerted upon the arms, as well as the sail, with the whole resistance which these arms and the edges of the flaps oppose to the motion of the wind-mill. By inspecting fig. 142 it will appear, that if the force upon the edges of the flaps, which Mr Beatson supposed to be twelve in number, amounts to thirty-six pounds, the force spent upon the bars CD, DG, GF, FE, &c. cannot be less than sixty pounds. Now, since these bars are acted upon with an equal force when the sails have the position AI, $1872 + 60 = 1932$ will be the force exerted upon the sail AI and its appendages, while the opposite force upon the bars and edges of the flaps, when returning against the wind, will be $36 + 60 = 96$ pounds, which is nearly $\frac{1}{20}$ of 1932, instead of $\frac{1}{32}$, as computed by Mr Beatson. Hence we may see the probable advantages of a screen over moveable flaps, as it will preserve not only the sails, but the arms and the frame which support it, from the action of the wind.

Buchanan's method.

A very ingenious method of bringing the sails back against the wind has been invented by Mr G. Buchanan of Edinburgh, and is represented in the annexed figure. The sails are attached, as usual, to the horizontal arms of the vertical axis CBA, and each of them moves horizontally round its own axis, as shown at H, *in an opposite direction to, and with half the angular direction of, the horizontal arms.*

Fig. 143.



In order to effect this, a toothed wheel *ab* is attached to the frame EF, and is therefore stationary while the mill revolves; *bc* is a toothed pinion working in *ab*, and moved by its axis *cd*, while this axis, fixed to the arm HI, revolves with the principal axis CBA, through which it passes at *k*. Two pinions *f*, *g*, are fixed to the ends of the axis *cd*, and work in the two wheels *h*, *i*, which are attached to the axis of the sails. They will, therefore, move round these sails in the same time, and with a velocity depending on the relative number of teeth in the wheels and pinions, and so adjusted as to give them half the angular velocity of the principal axis CBA. The wheel *ab* is made moveable round its axis, so that it may be shifted into any position, and keep the sails always to the wind.

By these means, when one of the sails M, is fully exposed to the action of the wind, the opposite one N, will only present its edge to the wind. As M advances, it gradually turns itself away from the wind, till it comes round into the position N, when the wind ceases to have any power over it. All the other sails do the same, and it will readily be seen, by constructing a diagram of the relative position of the sails at any point of their revolution, that the area of the returning sails exposed to the wind is always much less than the area of the sails urged forward by the wind.

Comparison between vertical and horizontal wind-mills.

We shall now conclude this chapter with a comparison of the power of horizontal and vertical wind-mills. It has been already stated, that Mr Smeaton rather underrated the former, when he maintained that they have only one eighth or one tenth the power of the latter. He observes, that when the vanes of a horizontal and a vertical mill are equal in dimensions, the power of the latter is four times that of the former, because, in the first case, only one sail is acted upon at once by the wind, while, in the second, all the four receive its impulse. This, however, is not strictly true, since the vertical sails are oblique to the direction of the wind. Let us suppose that the area of each sail is 100 square feet; then the power of the horizontal one will be 100, and the power of a vertical one may be called $100 \times \overline{\text{sine } 70°}^2$ (70° being the common angle of inclination) $= 88$ nearly; but since there are four vertical sails, the power of them all will be $4 \times 88 = 352$; so that the power of the horizontal sail is to that of the four vertical ones as 1 to 3·52, and not as 1 to 4, according to Mr Smeaton. But Mr Smeaton likewise observes, that if we consider the disadvantage which arises from the difficulty of getting the sails back against the wind, we need not wonder if horizontal wind-mills have only about one eighth or one tenth the power of the common sort. We have already seen, that the resistance occasioned by the return of the sails amounts to one twentieth of the whole force which they receive; by subtracting $\frac{1}{20}$, therefore, from $\frac{1}{3{\cdot}52}$, we shall find that the power of horizontal wind-mills is only $\frac{1{\cdot}03}{4{\cdot}40}$, or little more than one fourth that of vertical ones. This calculation proceeds upon a supposition that the whole force exerted upon vertical sails is employed in turning them round the axis of motion, whereas a considerable part of this force is lost in pressing the pivot of the axis or wind-shaft against its gudgeon. Mr Smeaton has overlooked this circumstance, otherwise he could never have maintained that the power of four vertical sails was quadruple the power of one horizontal sail, the dimensions of each being the same. Taking this circumstance into the account, we cannot be far wrong in saying, that, in theory at least, if not in practice, the power of a horizontal wind-mill is about one third or one fourth of the power of a vertical one when the quantity of surface and the form of the sails is the same, and when every part of the horizontal sails has the same distance from the axis of motion as the corresponding parts of the vertical sails. But if the horizontal sails have the position AI, EG, in fig. 142, instead of the position CA*dm*, CD*on*, their power will be greatly increased, though the quantity of surface is the same, because the part CP3*m*, being transferred to BI3*d*, has much more power to turn the sails.

Mechanical Agents not generally introduced.

In giving an account of the mechanical agents which are or may be employed to move machinery, we must enumerate *elastic springs*, *heated air*, *explosive mixtures*, and *carbonic acid gas*.

The spring is so common a first mover in our watches and clocks, and the method of rendering its varying force uniform by the fusee so well known, that it would be a waste of time to describe it here, and the more so as it will be referred to in another part of the work. See SCHOLIUM, p. 365. Heated air has been occasionally employed as a source of mechanical power. We have seen the model of a pump, in which the air in the barrel was rarefied by burning wood shavings at the top of the barrel, an air-tight cap being put on when the rarefaction was supposed to be a maximum. A certain quantity of water was thus raised above the valve at the bottom of the barrel, and the operation was repeated till the water rose to the desired height.

About ten or fifteen years ago a patent was taken out

Heated air-engine.

for a heated air-engine, by the Rev. Mr Stirling; and we believe that several such engines were actually constructed, and performed useful work, at Perth, Glasgow, and other places. The air was heated in an iron cylinder kept at a red heat, and after acting mechanically by its expansive force, it was cooled and returned to the cylinder by a very ingenious contrivance. The practical difficulty, however, which was encountered arose from the speedy destruction of the iron cylinder.

Atmospherical heated air-engine.

In the year 1824, Mr Samuel Brown took out a patent for what he called an atmospherical engine, in which a vacuum was created by burning coal or oil gas within the cylinder, and thus consuming the atmospherical air. The statements of the power of this engine were greatly exaggerated, and high expectations were formed of it, but we believe that it turned out a total failure.[1]

Explosive mixture engine.

The Rev. Mr Cecil[2] of Cambridge had, previously to Mr Brown's patent, invented an engine in which the power was obtained by taking advantage of the vacuum created by the explosion of a mixture of hydrogen gas and common air; and he also suggested that the expansive force of this explosion might be employed as the first mover of machinery. A mixture of *one* measure of hydrogen with two and a half measures of common air expands to three times its bulk on ignition, and then collapses instantly to about one half of the original volume of the mixture. If, therefore, we take a cylindrical vessel divided at one third of its length into two portions by a throttle valve (one which moves round its axis in the line of its diameter); if there be a solid piston in the shorter portion, and if at the end of the larger portion there is placed a light valve opening easily outward; then, supposing the throttle valve closed, and the piston lying down upon it, if the piston be now raised, and the mixed gases be permitted to flow in to supply the void left by the piston till it reach the end of its stroke; if at this time the valve be opened, and at the same instant a jet of flame be introduced at a touch-hole in the side of the cylinder to fire the explosive mixture, then the explosion will drive out the common air by the end valve from the larger portion, the valve will close, and the pressure of the atmosphere into the rare medium in the cylinder will force down the piston until it reaches nearly to the middle valve, when the mixed gases are again admitted, the middle valve closed, and the end one opened. The ascent of the piston will of course be produced by the action of a fly-wheel put in motion by the downward stroke.

In this machine the expansive force of the explosion does not produce the moving power, as it might be made to do. It merely drives out the common air, and produces a partial vacuum. The pressure of the atmosphere is in reality the moving power.

When Mr Faraday had made his beautiful discovery of the liquefaction of chlorine gas, Sir Humphry Davy communicated to the Royal Society of London a paper "*On the application of liquids formed by the condensation of gases as mechanical agents.*" In this way the attention of Mr Brunel was turned to the application of liquid carbonic acid gas as a first mover of machinery. Its remarkable powers of expansion by small degrees of heat pointed it out as peculiarly adapted for mechanical purposes, and the highest expectations where excited when Mr Brunel directed his great mechanical genius to the subject. He soon contrived a suitable mechanism for the application of this extraordinary agent, and took out a patent for it in England, and another in France in concert with MM. Ternaux and Delessert. In the apparatus which he prepared, the liquefied acid was at the temperature of 50°, and under the pressure of 30 atmospheres. The liquid gas was contained in two cylinders placed at the two extremities of the apparatus, and put in communication. The destruction of the equilibrium was effected by varying the temperature of the liquid in one of the condensers. Such, however, was the effect of the heat upon the liquid, that for a rise of temperature of 180° we obtain a pressure of 90 atmospheres, an enormous power, which having no resistance but that of the gas in the other condenser, tends to displace a piston with a force of $90 - 30 = 60$ atmospheres. Of this engine Mr Brunel constructed a working model, and he afterwards began a machine with a power of eight horses. In the course of his experiments, however, with this machine, he met with anomalies in the law of expansion of the liquefied gas which seemed to throw insuperable difficulties in his way, and led him to abandon his undertaking.

On the Construction of Wind-Mills.

At the time that Mr Brunel was occupied with this subject, Mr Faraday had obtained it only in small quantities; but M. Thilorier has lately discovered a new process, by which it may be obtained in quantities in a very few moments. From this cause M. Thilorier has had an opportunity of studying its properties; and we hope it may yet be found to realise at least some of the anticipations of earlier chemists. He found that the pressure of the vapour formed by the liquefied gas from 32° to 86° Fahr. amounts to from 36 to 73 atmospheres, and its volume from 20 to 29, the pressure being equal to an increase of one atmosphere to every centigrade degree, and the expansion being four times greater than that of atmospheric air. At 86° its specific gravity is 0·60, at 32° it is 0·83, and at — 68° it is 0·90.[3]

Comparison of the Quantity of Action furnished by different Mechanical Agents.

When a horse is employed in raising coals by means of a wheel and axle, and moves at the rate of about two miles an hour, Mr Fenwick found that he could continue at work 12 hours each day, two and a half of which were spent in short intervals of rest, when he raised a load of 1000 pounds avoirdupois, with a velocity of 13 feet per minute; and that he will exert a force of 75 pounds for nine hours and a half when moving with the same velocity. Mr Fenwick also found that 230 ale gallons of water delivered every minute on an overshot water-wheel, 10 feet in diameter; that a common steam-engine, with a cylinder 8 inches in diameter, and an improved engine with a cylinder 6·12 inches in diameter, will do the work of one horse, that is, will raise a weight of 1000 pounds avoirdupois through the height of 13 feet in a minute. It appears from Mr Smeaton's experiments, that Dutch sails in their common position with a radius of nine feet and a half, that Dutch sails in their best position with a radius of eight feet, and that his enlarged sails with a radius of seven feet, perform the same work as one man, or perform one fifth part of the work of a horse. Upon these facts we have constructed the following table, the first four columns of which are taken from Mr Fenwick's Essays on Practical Mechanics.

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[1] See Newton's Journal of Arts and Sciences, vol. viii. No. 44, p. 57; and Edinburgh Journal of Science, vol. i. p. 339.

[2] On the application of hydrogen gas to produce a moving power, Cambridge Transactions, vol. i.

[3] See Edinburgh Journal of Science, No. ix. p. 168; London and Edinburgh Philosophical Magazine, June 1836, No. 50, p. 583; and *Le Globe*, tom. iii. No. 29.

On the Construction of Wind-Mills.

Table showing the relative Strength of Overshot-Wheels, Steam-Engines, Horses, Men, and Wind-Mills of different kinds.

On the Construction of Wind-Mills.

Number of Ale Gallons delivered on an Overshot Wheel, 10 feet in diameter, every Minute.	Diameter of the Cylinder in the Common Steam-engine, in inches.	Diameter of the Cylinder of the improved Steam-engine, in inches.	Number of Horses working 12 Hours per Day, and moving at the rate of two Miles per Hour.	Number of Men working 12 Hours a Day.	Radius of Dutch Sails in their common position, in feet.	Radius of Dutch Sails in their best position, in feet.	Radius of Mr Smeaton's enlarged Sails, in feet.	Height to which these different Powers will raise 1000 pounds avoirdupois in a Minute.
230	8·	6·12	1	5	21·24	17·89	15·65	13
390	9·5	7·8	2	10	30·04	25·30	22·13	26
528	10·5	8·2	3	15	36·80	30·98	27·11	39
660	11·5	8·8	4	20	42·48	35·78	31·30	52
790	12·5	9·35	5	25	47·50	40·00	35·00	65
970	14·	10·55	6	30	52·03	43·82	38·34	78
1170	15·4	11·75	7	35	56·90	47·33	41·41	90
1350	16·8	12·8	8	40	60·09	50·60	44·27	104
1445	17·3	13·6	9	45	63·73	53·66	46·96	117
1584	18·5	14·2	10	50	67·17	56·57	49·50	130
1740	19·4	14·8	11	55	70·46	59·33	51·91	143
1900	20·2	15·2	12	60	73·59	61·97	54·22	156
2100	21·	16·2	13	65	76·59	64·50	56·43	169
2300	22·	17·	14	70	79·49	66·94	58·57	182
2500	23·1	17·8	15	75	82·27	69·28	60·62	195
2686	23·9	18·3	16	80	84·97	71·55	62·61	208
2870	24·7	19·	17	85	87·07	73·32	64·16	221
3055	25·5	19·6	18	90	90·13	75·90	67·41	234
3240	26·25	20·1	19	95	92·60	77·98	68·23	247
3420	27·	20·7	20	100	95·00	80·00	70·00	260
3750	28·5	22·2	22	110	99·64	83·90	73·42	286
4000	29·8	23·	24	120	104·06	87·63	76·68	312
4460	31·1	23·9	26	130	108·32	91·22	79·81	338
4850	32·4	24·7	28	140	112·20	94·66	82·82	364
5250	33·6	25·5	30	150	116·35	97·98	85·73	390

Dutch sails are always constructed so that the angle of weather may diminish from the centre to the extremity of the sail. They are concave to the wind, and are in their *common position* when their extremities are parallel to the plane in which they move, or perpendicular to the direction of the wind. Dutch sails are in their *best position* when their extremities make an angle of seven degrees with the plane of their motion. Mr Smeaton's enlarged sails are Dutch sails in their best position, but enlarged at their extremities.

It appears from M. Coulomb's experiments on Dutch wind-mills with rectangular sails, that when the distance between the extremities of two opposite sails is 66 feet French, and the breadth of each sail six feet, a wind moving at the rate of 20 feet per second will produce an effect equivalent to 1000 pounds raised through the space of 218 feet in a minute.

It will be seen in our article Steam-Engine, that the efficiency of a steam-engine is equal to the column of water in pounds raised at each stroke, multiplied by the length of the stroke and the number of strokes in a given time; and that what is called the *duty* of a steam-engine is equal to the same quantity divided by the number of bushels of coal consumed in the same time.

One of the old standard engines, as they were made in 1778, wrought pumps 17 inches in diameter at the depth of 58 fathoms, at the rate of six strokes in a minute, each stroke being $5\frac{1}{2}$ feet long. Its consumption of coal was 14,080 bushels in 61 days, hence its duty was 6,901,753.

In the year 1793, the improvements of Messrs Boulton and Watt were so important, that the average duty of 17 engines of their construction was 19,569,000, being an increase of duty in the ratio of 28 to 10.[1]

Since that time the use of steam of high temperature, the construction of fire-places with superior drafts, or iron tubes passing through the boiler, and other improvements in the execution of the machinery, have given such additional power to the steam-engine, that in 1829 the highest monthly average duty of one of the engines was 79,000,000, surpassing in duty the engine of 1778 in the ratio of $11\frac{1}{2}$ to 1, and those of 1793 as 4 to 1.

Mr Taylor expresses the improvement on steam-engines by the number of bushels of coal that are requisite to perform a given piece of work.

With the early steam-engine	16 bushels.
During Boulton and Watt's patent	4
About the year 1825	2
The best Cornish engines	1

The following interesting comparisons have been given by Sir John Herschel. "It is well known," says he, "to modern engineers, that *there is virtue* in a bushel of coals, properly consumed, to raise seventy millions of pounds weight a foot high. This is actually the *average* effect of an engine at this moment working in Cornwall. Let us pause

[1] According to Watt and Boulton, one of their steam-engines, with a cylinder 31 inches in diameter, and which makes 17 double strokes per minute, is equivalent to 40 horses working day and night; that is, to 101 horses working nine hours and a half, the time of constant exertion in the preceding table. When the cylinder is 19 inches in diameter, and the engine makes 25 strokes of four feet each per minute, its power is equivalent to twelve horses working constantly, or thirty horses working nine hours and a half; and when the cylinder is 24 inches in diameter, and the engine makes 22 strokes of five feet each in a minute, its power is equal to that of 20 horses working constantly, or 50 horses working nine hours and a half.

On the Construction of Wheel-Carriages.

a moment, and consider what this is equivalent to in matters of practice.

"The ascent of Mont Blanc from the valley of Chamouni is considered, and with justice, as the most toilsome feat that a strong man can execute in two days. The combustion of two pounds of coal would place him on the summit.

"The Menai Bridge, one of the most stupendous works of art that has been raised by man in modern ages, consists of a mass of iron not less than four millions of pounds in weight, suspended at a medium height of about 120 feet above the sea. The consumption of seven bushels of coal would suffice to raise it to the place where it hangs.

"The great pyramid of Egypt is composed of granite. It is 700 feet in the side of its base, and 500 in perpendicular height, and stands on eleven acres of ground. Its weight is therefore 12,760 millions of pounds, at a medium height of 125 feet; consequently it would be raised by the effort of about 630 chaldrons of coal, a quantity consumed in some founderies in a week.

"The annual consumption of coal in London is estimated at 1,500,000 chaldrons. The effort of this quantity would suffice to raise a cubical block of marble, 2200 feet in the side, through a space equal to its own height, or to pile one such mountain upon another.

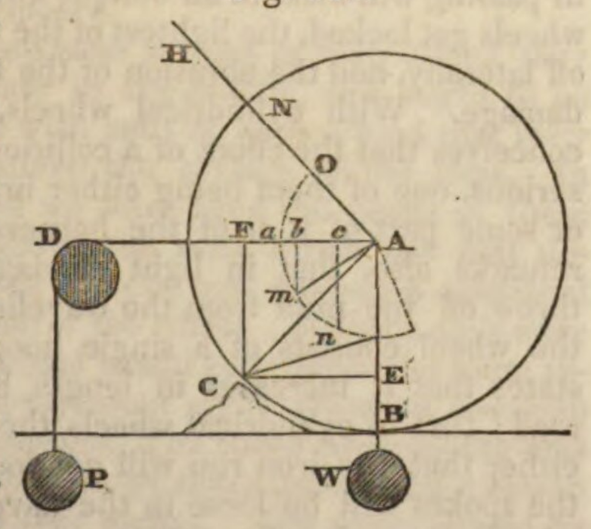
"The Monte Nuovo, near Pozzuoli (which was erupted in a single night by volcanic fire), might have been raised by such an effort from a depth of 40,000 feet, or about eight miles. It will be observed, that in the above statement the inherent power of fuel is, of necessity, greatly underrated. It is not pretended by engineers that the economy of fuel is yet pushed to its utmost limit, or that the whole effective power is obtained in any application of fire yet devised; so that were we to say 100 millions instead of 70, we should probably be nearer the truth."

CHAP. VIII.—ON THE CONSTRUCTION OF WHEEL-CARRIAGES.

On the size of carriage-wheels.

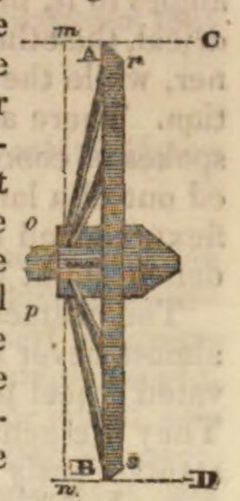
It is evident, from Cor. 8, p. 360, that when a wheel surmounts an obstacle, it acts as a lever of the first kind, and that its power to overcome such resistances increases with its diameter. The power of the force P, for example, to raise the wheel NB over the eminence C, is proportional to the vertical lever FC, which increases with the diameter of the wheel, while the lever of resistance FA, by which the weight of the wheel acts, remains unchanged; hence we see the advantages of large wheels for overcoming such obstacles as generally resist the motion of wheel-carriages. There are some circumstances, however, which, independent of the additional weight and expense of large wheels, prescribe limits to their size. If the radius AC of the wheel exceeds the height of that part of the horse to which the traces are attached, the line of traction DA will be oblique to the horizon, and part of the power P will be employed in pressing the wheel upon the ground. A wheel exceeding four and a half feet radius, which is the general distance from the ground of that part of the horse to which the traces are attached, has still the advantage of a smaller wheel; but when we consider that the traces or poles of the cart will, in this case, rub against the flanks of the horses, so that the power of the wheel is diminished by the increase of its weight, we shall be convinced that no power is gained by making the radius of the wheels greater than four and a half feet. Even this size is too great, as shall be afterwards shown when we treat of the line of traction, so that we may safely assert that the diameters of wheels should never be greater than six feet. The fore-wheels of our carriages are still unaccountably small, and it is not uncommon to see carts moving upon wheels scarcely fourteen inches in diameter. The convenience of turning is urged as the reason for diminishing the fore-wheels of carriages, and the facility of loading the cart is considered as a sufficient reason for using wheels so small as fourteen inches. The first of these advantages, however, may be obtained by going to the end of a street, or to a proper place for turning the carriage; and a few additional turns of a windlass will be sufficient to convey the heaviest loads into carts mounted on high wheels.

Fig. 144.



The next thing to be determined is the shape of the wheels. A cylindrical wheel, with the spokes perpendicular to the naves, is perhaps the form which every mechanic would give to his wheels, before he had heard of the advantages of concave or dishing wheels, or those which have inclined spokes and conical rims. It has been alleged, indeed, and with truth, that the form represented in fig. 145, where A*r*, B*s* is the conical rim, and *o*A, *p*B the inclined spokes, renders the wheel stronger than it would otherwise be; that by extending the base of the carriage it prevents it from being overturned; that it hinders the fellies from rubbing against the load or the sides of the cart; and that when one wheel falls into a rut, and therefore supports more than one half of the load, the spokes are brought into a vertical position, which renders them more capable of sustaining the additional weight.

Fig. 145.



Two of these advantages exist only in very bad roads; and if they are necessary, in a country like this, where the roads are so excellently made and so regularly repaired, they can easily be procured, by making the axle-tree a few inches longer, and increasing the strength of the spokes. But it is allowed on all hands that perpendicular spokes are preferable on level ground. The inclination of the spokes, therefore, which renders concave wheels advantageous in rugged and unequal roads, renders them disadvantageous when the roads are in good order; and where the good roads are more numerous than the bad ones, as they certainly are in this country, the disadvantages of concave wheels must overbalance their advantages. It is true, indeed, that in concave wheels the spokes are in their strongest position when they are exposed to the severest strains, that is, when one wheel is in a deep rut, and sustains more than one half of the load; but it is equally true, that on level ground, where the spokes are in their weakest position, a less severe strain, by continuing for a much longer time, may be equally if not more detrimental to the wheel.

We shall now endeavour to show that concave dishing wheels are more expensive, more injurious to the roads, and more liable to be broken by accidents, than those wheels in which the spokes are perpendicular to the naves. By inspecting fig. 145, it will appear that the whole of the pressure which the wheel AB sustains is exerted along the inclined spoke *ps*, and therefore acts obliquely on the level ground *n*D, whether the rims are conical or cylindrical. This oblique action must necessarily injure the roads, by loosening the stones more between B and D than between B and *n*; and if the load were sufficiently great, the stones would start up between *s* and D. The texture of the roads, indeed, is sufficiently firm to prevent this from tak-

On the Construction of Wheel-Carriages.

ing place; but, in consequence of the oblique pressure, the stones between *s* and D will at least be loosened, and, by admitting the rain, the whole of the road will be materially damaged. But when the spokes are perpendicular to the nave, as *pn*, and when the rims *m*A, *n*B are cylindrical, or parallel to the ground, the weight sustained by the wheel will act perpendicularly upon the road; and however much that weight is increased, its action can have no tendency to derange the materials of which it is composed, but is rather calculated to consolidate them, and render the road more firm and durable.

It was observed that concave wheels are more expensive than plane ones. This additional expense arises from the greater quantity of wood and workmanship which the former require; for in order that dishing wheels may be of the same perpendicular height as plane ones, the spokes of the former must exceed in length those of the latter, as much as the hypothenuse *o*A of the triangle *oAm* exceeds the side *om*; and therefore the weight and the resistance of such wheels must be proportionably great. The inclined spokes, too, cannot be formed nor inserted with such facility as perpendicular ones. The extremity of the spoke which is fixed into the nave is inserted at right angles to it, in the direction *op*; and if the rims are cylindrical, the other spoke should be inserted in a similar manner, while the intermediate portion has an inclined position. There are therefore two flexures or bendings in the spokes of concave wheels, which requires them to be formed out of a larger piece of wood than if they had no such flexures, and renders them liable to be broken by any sudden strain at the points of flexure.

The obstacles which carriages have to encounter are almost never spherical protuberances, that permit the elevated wheel to resume by degrees its horizontal position. They are generally of such a nature that the wheel is instantaneously precipitated from their top to the level ground. Now the momentum with which the wheel strikes the ground is very great, arising from a successive accumulation of force. The velocity of the elevated wheel is considerable when it reaches the top of the eminence; and while it is tumbling into the level ground it is receiving gradually that proportion of the load which was transferred to the other wheel, till, having recovered the whole, it impinges against the ground with great force. But in concave wheels the spoke which then strikes the ground is in its weakest position, and therefore much more liable to be broken by the impetus of the fall than the spokes of the lowest wheel by the mere transference of additional weight; whereas, if the spokes be perpendicular to the nave, they receive this sudden shock in their strongest position, and are in no danger of giving way to the strain.

In the preceding observations we have supposed the rims of the wheels to be cylindrical. In concave wheels, however, the rims are uniformly made of a conical form, as A*r*, B*s*, fig. 145, which increases the disadvantages which we have ascribed to them. Mr Cumming, in a late Treatise on Wheel-Carriages, points out the disadvantages of conical rims, and the propriety of making them cylindrical; but we are of opinion that he has ascribed to conical rims several disadvantages which arise chiefly from an inclination of the spokes. He insists much upon the injury done to the roads by the use of conical rims; yet though we are convinced that they are more injurious to pavements and highways than cylindrical rims, we are equally convinced that this injury is occasioned chiefly by the oblique pressure of the inclined spokes. The defects of conical rims are numerous and obvious. Every cone that is put in motion upon a plane surface will revolve round its vertex, and if force is employed to confine it to a straight line, the smaller parts of the cone will be dragged along the ground, and the friction greatly increased. Now when a carriage moves upon conical wheels, one part of the cone rolls while the other is dragged along, and though confined to a rectilineal direction by external force, their natural tendency to revolve round their vertex occasions a great and continued friction upon the linch-pin, the shoulder of the axle-tree, and the sides of deep ruts.

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Mr Edgeworth made some interesting experiments on this subject. He compared a pair of conical wheels, whose inside diameter was thirty-three, while their outside diameter was twenty-seven, with a pair of cylindrical ones, the diameter of which was as thirty-four. When they moved on smooth deal-boards, the *conical wheels required an addition of* 50 *per cent. to the moving power* in order to make their velocity equal to that of the cylindrical ones. On a fine gravel road, the addition required was only eight per cent. while on a newly-made coarse road there was a perceptible difference between the two kinds of wheels, although they were only eight inches high and four broad.

A very able paper on the wheels of carriages, containing views different from those we have given above, has been recently published[1] by Mr James Walker, civil engineer, and containing the substance of his examination before the House of Commons. When the road is perfectly smooth, and the motion of the carriage regular, and without any tendency to strain in a lateral direction, he considers the cylindrical wheel as decidedly the best, "because the power of the spokes of the wheel to oppose such a pressure is greater when they are perfectly upright under their load, and because the joints, being square, can be made with greater care and accuracy than bevelled ones." As roads, however, are not of this description, he considers the cylindrical wheel as deficient in bracing; and he remarks, "that wheels so constructed soon get loose at their joints; that the whole wheel gets crippled in consequence; and that, for *durability under heavy work and rough roads*, such wheels will not answer the purpose." Besides the strength arising from the bracing of the conical wheel and bent axle, Mr Walker ascribes to it the following advantages. As these wheels project outwards at top, the rims of carriage-wheels coming into collision with each other in passing will meet in an oblique direction; and unless the wheels get locked, the lightest of the two carriages is pushed off laterally, and the abrasion of the fellies may be the only damage. With cylindrical wheels, on the contrary, he conceives that the effect of a collision would be much more serious, one of them being either brought to a dead stand, or some part of it or of the harness broken. Mr Walker remarks also, that in light carriages the dished wheels throw off the mud from the traveller. When the tire of the wheel consists of a single hoop of iron, Mr Walker states that it increases in length by beating against the road; that in cylindrical wheels the result of this will be, either that the iron rim will get loose upon the fellies, or the spokes will be loose in the nave; whereas, in dished wheels, the only effect of an expansion of the tire will be that the spokes will become more upright, or the wheel a little less dishing. This argument, however, we must observe, falls to the ground when the tire consists of separate segments.

The amount of Mr Walker's argument in favour of dished wheels is, that such wheels are a firmer and more durable piece of carpentry. This argument, however, loses all its force if cylindrical wheels could be made as strong as dished ones by any new combination of spokes and fellies, which have the effect of bracing. That such a combination is possible we cannot doubt; and when we consider the smooth and level surface which prevails under an im-

[1] Edinburgh Journal of Science, vol. i. p. 274.

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proved system of road-making, we should be disposed still to adopt the cylindrical wheel for the sake of the horse that is to draw it, or rather for the purpose of obtaining a greater load from the same horse, even though the wheels might not last so long as dished ones. If the fellies were connected with the nave by means of spokes equally but oppositely inclined to the strongest axle, we are persuaded that a cylindrical wheel might be made as firm as a dished wheel, and of even greater strength in resisting any sudden impulse against the road.

The shape of the wheels being thus considered, we must now attend to some particular parts of their construction. The tire or iron plates of which the rims are composed should never be less than three inches in breadth, as narrow rims sink deep into the ground, and therefore injure the roads and fatigue the horses.[1] When any load is supported upon two points, each point supports one half of the weight; if the points are increased to four, each will sustain one fourth of the load, and so on; the pressure upon each point of support diminishing as the number of points increases. If a weight therefore is supported by a broad surface, the points of support are infinite in number, and each of them will bear an infinitely small portion of the load; and, in the same way, every finite portion of this surface will sustain a part of the weight inversely proportional to the number of similar portions which the surface contains. Let us now suppose that a cart carrying a load of sixteen hundredweight is supported upon wheels whose rims are four inches in breadth, and that one of the wheels passes over four stones, each of them an inch broad and equally high, and capable of being pulverized only by a pressure of four hundred pounds weight. Then as each wheel sustains one half of the load, and as the wheel which passes over the stones has four points of support, each stone will bear a weight of two hundredweight, and therefore will not be broken. But if the same cart, with rims only two inches in breadth, should pass the same way, it will cover only two of the stones; and the wheel having only two points of support, each stone will be pressed with a weight of four hundredweight, and will therefore be reduced to powder. Hence we may infer that narrow wheels are in another point of view injurious to the roads, by pulverizing the materials of which they are composed.

As the rims of wheels wear soonest at their edges, they should be made thinner in the middle, and ought to be fastened to the fellies with nails of such a kind that their heads may not rise above the surface of the rims. In some military waggons we have seen the heads of these nails rising an inch above the rims, which not only destroys the pavements of streets, but opposes a continual resistance to the motion of the wheel. If these nails were eight in number, the wheel would experience the same resistance as if it had to surmount eight obstacles, one inch high, during every revolution. The fellies on which the rims are fixed should in carriages be three inches and a fourth deep, and in waggons four inches. The naves should be thickest at the place where the spokes are inserted; and the holes in which the spokes are placed should not be bored quite through, as the grease upon the axle-tree would insinuate itself between the spoke and the naves, and prevent that close adhesion which is necessary to the strength of the wheel.

On the Position of the Wheels.

It must naturally occur to every person reflecting upon this subject, that the axle-trees should be straight and the wheels perfectly parallel, so that they may not be wider at their highest than at their lowest point, whether they are of a conical or of a cylindrical form. In this country, however, the wheels are always made concave, and the ends of the axle-trees are universally bent downwards, in order to make them spread at the top and approach nearer below. In some carriages which we have examined, where the wheels were only four feet six inches in diameter, the distance of the wheels at top was fully six feet, and their distance below only four feet eight inches. By this foolish practice the very advantages which may be derived from the concavity of the wheels are completely taken away, while many of the disadvantages remain; more room is taken up in the coach-house, and the carriage is more liable to be overturned by the contraction of its base.

On the Construction of Wheel-Carriages.

With some mechanics it is a practice to bend the ends of the axle-trees forwards, and thus make the wheels wider behind than before. This blunder has been strenuously defended by Mr Henry Beighton, who maintains that wheels in this position are more favourable for turning, since, when the wheels are parallel, the outermost when turning would press against the linch-pin, and the innermost would rest against the shoulder of the axle-tree. In rectilineal motions, however, these converging wheels engender a great deal of friction both on the axle and the ground, and must therefore be more disadvantageous than parallel ones.

On the Line of Traction, and the Method by which Horses exert their Strength.

M. Camus attempted to show that the line of traction should always be parallel to the ground on which the carriage is moving, both because the horse can exert his greatest strength in this direction, and because the line of draught, being perpendicular to the vertical spoke of the wheel, acts with the largest possible lever. M. Couplet, however, considering that the roads are never perfectly level, and that the wheels are constantly surmounting small eminences even in the best of roads, recommends the line of traction to be oblique to the horizon. By this means the line of draught HA (which is by far too much inclined in fig. 144) will in general be perpendicular to the lever AC which mounts the eminence, and will therefore act with the longest lever when there is the greatest necessity for it. We ought to consider, also, that when a horse pulls hard against any load, he always brings his breast nearer the ground; and therefore it follows, that if a horizontal line of traction is preferable to all others, the direction of the traces should be inclined to the horizon when the horse is at rest, in order that it may be horizontal when he lowers his breast and exerts his utmost force. The particular manner, however, in which living agents exert their strength against great loads, seems to have been unknown both to Camus and Couplet, and to many succeeding writers upon this subject. It is to M. Deparcieux, an excellent philosopher and ingenious mechanic, that we are indebted for the only accurate information with which we are furnished; and we are sorry to see that philosophers who flourished after him have overlooked his important instructions. In his memoir on the draught of horses he has shown, in the most satisfactory manner, that animals draw by their weight, and not by the force of their muscles. In four-footed animals, the hinder feet is the fulcrum of the lever by which their weight acts against the load, and when the animal pulls hard, it depresses its chest, and thus increases the lever of its weight, and diminishes the lever by which the load resists its efforts. Thus, in fig. 144, let P be the load, AD the line of traction, and let us suppose FC to be the hinder leg of the horse, and AE part of its body, A its

[1] The tire of the wheels of coaches and light carriages is less than *two inches* wide. That of the mail-coaches is *an inch and a half*; and, as it is much rounded, not above *an inch* of it touches the road.

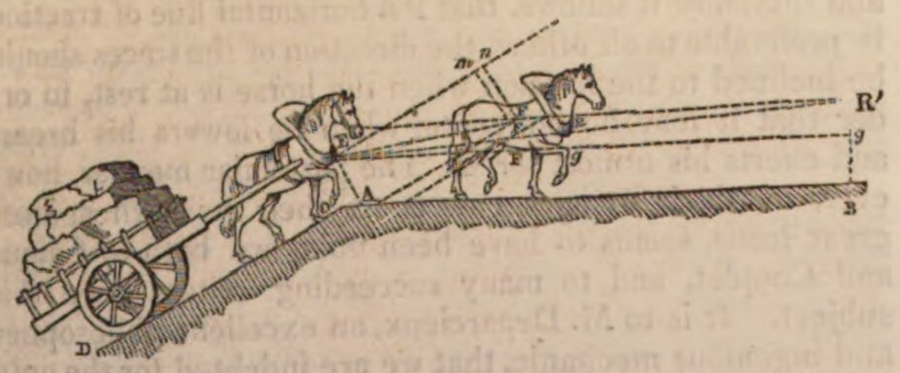
On the Construction of Wheel-Carriages.

chest or centre of gravity, and CE the level road. Then AFC will represent the crooked lever by which the horse acts, which is equivalent to the straight one AC. But when the horse's weight acts downwards at A, so as to drag forward the rope AD and raise the load P, CE will represent the power of the lever in this position, or the lever of the horse's weight, and CF the lever by which it is resisted by the load, or the lever of resistance. Now if the horse lowers its centre of gravity A, which it always does when it pulls hard, it is evident that CE, the lever of its weight, will be increased, while CF, the lever of its resistance, will be diminished, for the line of traction AD will approach nearer to CE. Hence we see the great benefit which may be derived from large horses; for the lever AC necessarily increases with their size, and their power is always proportioned to the length of this lever, their weight remaining the same. Large horses, therefore, and other animals, will draw more than small ones, even though they have less muscular force, and are unable to carry such a heavy burden. The force of the muscles tends only to make the horse carry continually forward his centre of gravity; or, in other words, the weight of the animal produces the draught, and the play and force of its muscles serve to continue it.

From these remarks, then, we may deduce the proper position of the line of traction. When the line of traction is horizontal, as AD, the lever of resistance is CF; but if this line is oblique to the horizon, as A*d*, the lever of resistance is diminished to C*f*, while the lever of the horse's weight always remains the same. Hence it appears, that inclined traces are much more advantageous than horizontal ones, as they uniformly diminish the resistance to be overcome. Deparcieux, however, has investigated experimentally the most favourable angle of inclination, and found, that when the angle DAF made by the trace A*d* and a horizontal line is fourteen or fifteen degrees, the horses pulled with the greatest facility and force. This value of the angle of draught will require the weight of the spring-tree bar, to which the traces are attached in four-wheeled carriages, to be *one half* of the height of that part of the horse's breast to which the fore end of the traces is connected.

When several horses are yoked in the same carriage, as represented in fig. 146, and when the declivity changes,

Fig. 146.



the length of the traces has a considerable influence upon the draught. From the point E, where the traces are fastened to the horse next the load, draw ER to the same point in the second horse R, and let R′ be another position of the second horse; it is required to find the difference of effect that will be produced by placing the second horse at R or at R′, or the comparative advantages of short and long traces. From R′, the point where the traces are fixed, draw R′F′E; and from E draw E*mn* parallel to the declivity DA. Take EF = EF′ to represent the power of the horse in the direction of the traces, which will be the same whether he is yoked at R or at R′; draw EA perpendicular to DA, F*n*, F′*m* parallel to EA, and Fφ, F′*f* parallel to E*n*. Then, since the second horse when at R pulls with a force represented by FE, in the direction FE, we may resolve this force into the two forces E*n*, Eφ, one of which E*n* is solely employed in dragging the cart up the inclined plane DA, while the other Eφ is solely employed in pressing the first horse E to the ground. Let the horse be now removed from R to R′, the direction of the traces becomes RF′F, and F′E = FE is the power exerted by the horse at R′ and the direction in which it is exerted. But this force is equivalent to the forces E*m*, E*f*, the first of which acts directly against the load, while the other presses the horse against the ground. Hence we see the disadvantages of long traces, for the force which draws the load when the horse is at R′ is to the force when the horse is at R, as E*m* to E*n*, and the forces which press the horse upon the ground as E*f* to φ, or as F′*m* to F*n*. Now Eφ = F*n* = FE × sin. *n*EF; hence Eφ = FE × sin. $\overline{(n\mathrm{E}g' - \mathrm{FE}g')}$ (*g*′E being parallel to AB′) and E*n* = EF × cos. (*n*E*g*′ — FE*g*′). In like manner we have E*f* = FE × sin. (*n*E*g*′ — F′E*g*′), and E*m* = EF × cos. (*n*E*g*′ — F′E*g*′). Now sin. FE*g*′ = sin. FE*g* = $\frac{\mathrm{R}g}{\mathrm{ER}'}$, and sin. FE*g* = $\frac{\mathrm{R}'g'}{\mathrm{ER}'} = \frac{\mathrm{R}g}{\mathrm{ER}'}$; but R*g* = R′*g*′ = BR — EQ = BR — BR × cos. *n*E*g*′ = BR × (1 — cos. *n*E*g*). By substituting this value in the equations which contain the values of Eφ, E*n*, E*f*, E*m*, and considering that the angles FE*g*′, F′E*g* are always so small that their arcs differ very little from their sines, we have

$$\mathrm{FE}g = \frac{\mathrm{BR} \times \overline{1 - \cos.\, n\mathrm{E}g}}{\mathrm{ER}}, \text{ and}$$

$$\mathrm{F}'\mathrm{E}g' = \frac{\overline{\mathrm{BR} \times 1 \cos.\, n\mathrm{E}g}}{\mathrm{ER}'}.$$

By substituting these values in the preceding equations, we have

$$\mathrm{E}\varphi = \mathrm{EF} \times \sin.\left(n\mathrm{E}g - \frac{\overline{\mathrm{BR} \times 1 - \cos.\, n\mathrm{E}g}}{\mathrm{ER}}\right),$$

$$\mathrm{E}fn = \mathrm{EF} \times \sin.\left(n\mathrm{E}g - \frac{\overline{\mathrm{BR} \times 1 - \cos.\, n\mathrm{E}g}}{\mathrm{ER}'}\right),$$

$$\mathrm{E}n = \mathrm{EF} \times \cos.\left(n\mathrm{E}g - \frac{\overline{\mathrm{BR} \times 1 - \cos.\, n\mathrm{E}g}}{\mathrm{ER}}\right),$$

$$\mathrm{E}m = \mathrm{EF} \times \cos.\left(n\mathrm{E}g - \frac{\overline{\mathrm{BR} \times 1 - \cos.\, n\mathrm{E}g}}{\mathrm{ER}'}\right).$$

If AB is horizontal, and the declivity AD = $\frac{1}{6}$, we shall have *n*E*g* = 9° 28′, or in parts of the radius = 0·16522, and cos. *n*E*g* = 0·98638. Then, if EF = 200 pounds, BR = $3\frac{1}{2}$ feet, ER = 8 feet, ER′ = 12 feet, then we shall have, from the preceding formulæ, Fφ = 31·716 pounds, E*f* = 32·350 pounds, E*n* = 197·470 pounds, and E*m* = 197·404. Hence an additional length of four feet to traces eight feet long presses the horse E to the ground with an additional force of 32·250—31·716 = 0·534 pounds, and diminishes the effect of the other horse by 0·066 pounds.

On the Position of the Centre of Gravity, and the Manner of disposing the Load.

If the axle-tree of a two-wheeled carriage pass through the centre of gravity of the load, the carriage will be in equilibrio in every position in which it can be placed with respect to the axle-tree; and in going up and down hill the whole load will be sustained by the wheels, and will have no tendency either to press the horse to the ground or to raise him from it. But if the centre of gravity is above the axle-tree, as it must necessarily be, according to the present construction of wheel-carriages, a great part of the load will be thrown on the back of the horses from

On the Construction of Wheel-Carriages.

the wheels when going down a steep road, and thus tend to accelerate the motion of the carriage, which the animal is striving to prevent; while, in ascending steep roads, a part of the load will be thrown behind the wheels, and tend to raise the horse from the ground, when there is the greatest necessity for some weight on his back to enable him to fix his feet in the earth, and overcome the great resistance which is occasioned by the steepness of the road. On the contrary, if the centre of gravity is below the axle, the horse will be pressed to the ground in going up hill, and lifted from it when going down. In all these cases, therefore, where the centre of gravity is either on the axle-tree or directly above it or below, the horse will bear no part of the load in level ground. In some situations the animal will be lifted from the ground when there is the greatest necessity for his being pressed to it, and he will sometimes bear a great proportion of the load when he should rather be relieved of it.

The only way of remedying these evils is to assign such a position to the centre of gravity, that the horse may bear some portion of the weight when he must exert great force against the load, that is, in level ground, and when he is ascending steep roads; for no animal can pull with its greatest effort unless it is pressed to the ground. Now this may be in some measure effected in the following manner. Let BCN (fig. 144) be the wheel of a cart, AD one of the shafts, D that part of it where the cart is suspended on the back of the horse, and A the axle-tree; then, if the centre of gravity of the load is placed at *m*, a point equidistant from the two wheels, but below the line DA, and before the axle-tree, the horse will bear a certain weight on level ground, a greater weight when he is going up hill and has more occasion for it, and less weight when he is going down hill, and does not require to be pressed to the ground: all this will be evident from the figure. When we recollect that the shaft DA is horizontal, the centre of gravity will press more upon the point of suspension D the nearer it comes to it; or the pressure upon D, or the horse's back, will be proportional to the distance of the centre of gravity from A. If *m*, therefore, be the centre of gravity, *b*A will represent its pressure upon D, when the shaft DA is horizontal. When the cart is ascending a steep road, AH will be the position of the shaft, the centre of gravity will be raised to *a*, and *a*A will be the pressure upon D. But if the cart is going down hill, AC will be the position of the shaft, the centre of gravity will be depressed to *n*, and *c*A will represent the pressure upon the horse's back. The weight sustained by the horse, therefore, is properly regulated by placing the centre of gravity at *m*. We have still, however, to determine the proper length of *ba* and *bm*, the distance of the centre of gravity from the axle, and from the horizontal line DA; but as these depend upon the nature and inclination of the road, upon the length of the shaft DA, which depends on the size of the horse, on the magnitude of the load, and on other variable circumstances, it would be impossible to fix their value. If the load, along with the cart, weighs 400 pounds, if the distance DA be eight feet, and if the horse should bear 50 pounds of the weight; then *b*A should be one foot, which, being one eighth of DA, will make the pressure upon D exactly 50 pounds. If the road slopes four inches in a foot, *bm* must be four inches, or the angle *b*A*m* should be equal to the inclination of the road; for then the point *m* will rise to *a* when ascending such a road, and will press with its greatest force on the back of the horse.

When carts are not made in this manner, we may in some degree obtain the same end by judiciously disposing the load. Let us suppose that the centre of gravity is at O when the cart is loaded with homogeneous materials, such as sand, lime, &c.; then if the load is to consist of heterogeneous substances, or bodies of different weights, we should place the heaviest at the bottom and nearest the front, which will not only lower the point *o*, but will bring it forward, and nearer the proper position *m*. Part of the load, too, might be suspended below the fore part of the carriage in dry weather, and the centre of gravity would approach still nearer the point *m*. When the point *m* is thus depressed, the weight on the horse is not only judiciously regulated, but the cart would be prevented from overturning; and in rugged roads the weight sustained by each wheel would be in a great degree equalized.

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Composition for diminishing the Friction of the Wheels of Carriages, &c.

The following composition has been very recently discovered by Mr Partridge, and secured by patent.

"To about twenty gallons of clear soft water apply three or four pounds of fresh lime, put them into a cask, and stir them well about; then let it stand about twenty-four hours, or until the water is quite clear, when it may be drawn off as wanted. The lime-water should be stirred up every five or six days, that the water may be kept fully impregnated with the lime. To one part or proportion of this solution of lime water add one part or proportion of olive oil. These ingredients are to be placed in an open vessel, and whisked, beat, or stirred well together until they are completely blended; or they may be placed in a bottle or jar, and well shaken, until the same effect takes place. The composition of lime-water and oil will then have the consistency and appearance of thick cream; and if the composition made from the above proportions should be found too thick, it may be thinned or reduced in consistency by adding a little more oil; and I would remark, that the composition should be well shaken or mixed up before using; and the lime-water should be kept free from air, and as cool as possible.

"For axle-trees and other bearings this composition will be found superior to pure oil, and will not be consumed so rapidly.

"To render this composition more applicable to the lubrication of cogs or teeth of wheels, Mr Partridge prefers whale or other common oil, which may be used in one part or proportion to two parts or proportions of lime-water; and when perfectly commixed, as before stated, to it is to be added palm oil or tallow, or both, and well rubbed or ground therewith until the composition assumes the appearance of thick paste, when a small quantity of carbonaceous matter, such as plumbago, black lead, or soot, may be added, and when incorporated with each other, the composition will be fit for use."[1]

Description of different Carriages.

In figure 147 is represented a carriage invented by Mr Richard, a physician in Rochelle, which moves without horses, merely by the exertion of the passengers. The machinery by which this is effected is placed in a box behind the carriage, and is shown in fig. 148, where AA is a small axis fixed into the box, and E a pulley over which a rope passes, whose two extremities are tied to the ends of the levers or treddles C, D: the other ends of the levers are fixed by joints to the cross-beam MN. The cranks FF are fixed to the axle KL, and move upon it as a

[1] See the London Journal and Repertory of Arts, &c. No. 55, October 1836, p. 33.

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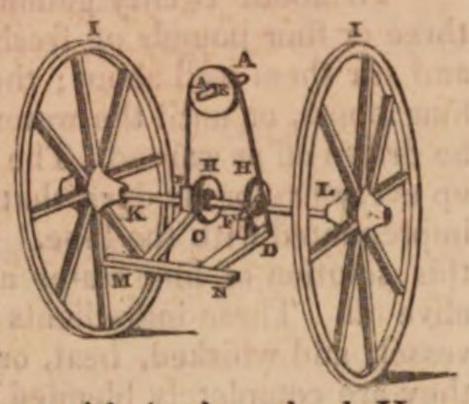
Fig. 147.

centre. Each of them has a detent tooth at F, which catches in the teeth of the wheels H, H, so that they can move from F to H without moving the wheel, but the detent tooth catches in the teeth of the wheels when the cranks are brought backward, and therefore bring the wheel along with them. When the foot of the passenger, therefore, is placed upon the treddle D, it brings down the crank F, and along with it the wheel H, so that the large wheels fixed on the same axis perform part of a revolution; but when D is depressed, the rope DA descends, the extremity C of the other treddle rises, and the crank F rising along with it, takes into the teeth of the wheel H, so that when the elevated treddle C is depressed, the wheels H, H, and consequently the wheels I, I, perform another part of a revolution. In this way, by continuing to work at the treddles, the machine advances with a regular pace.

Fig. 148.



A carriage of this kind, where the mechanism is much more simple and beautiful than that which we have described, has been lately invented and constructed by Mr Nasmyth of Edinburgh, a gentleman whose mechanical genius is scarcely inferior to his talents as a painter. The

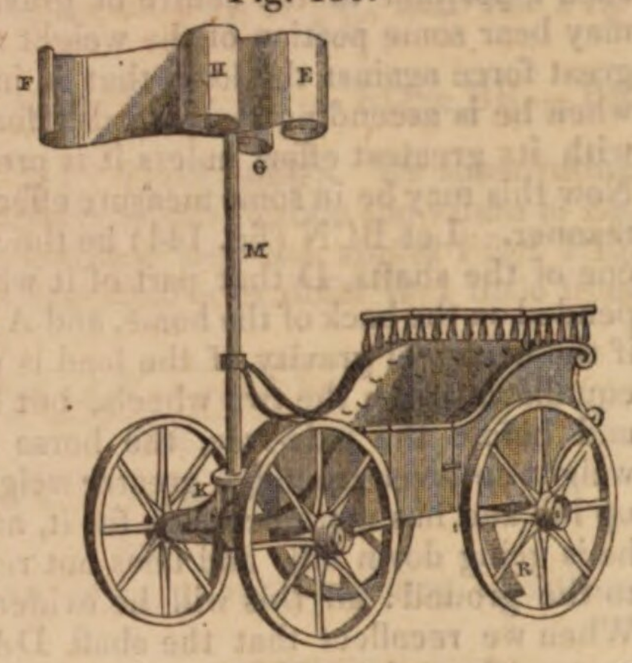
Fig. 149.

pulley E and axle AA are rendered unnecessary; leather straps are substituted in place of the cranks F, F, and the whole mechanism is contained in two small cylindrical boxes about six inches in diameter and one and a half broad.

A carriage driven by the action of the wind is exhibited in fig. 149. It is fixed on four wheels, and moved by the impulse of the wind upon the sails C, D, being guided by the rudder E. Carriages of this kind will answer very well in a level country, where the roads are good and the wind fair; and are said to be much used in China. In Holland they sometimes use similar vehicles for travelling upon the ice; but they have a sledge instead of wheels, so that if the ice should happen to break, there will be no danger of sinking. Stephinus, a Dutchman, is said to have constructed one of these carriages with wheels, which travelled at the rate of twenty-one miles an hour with a very strong wind.

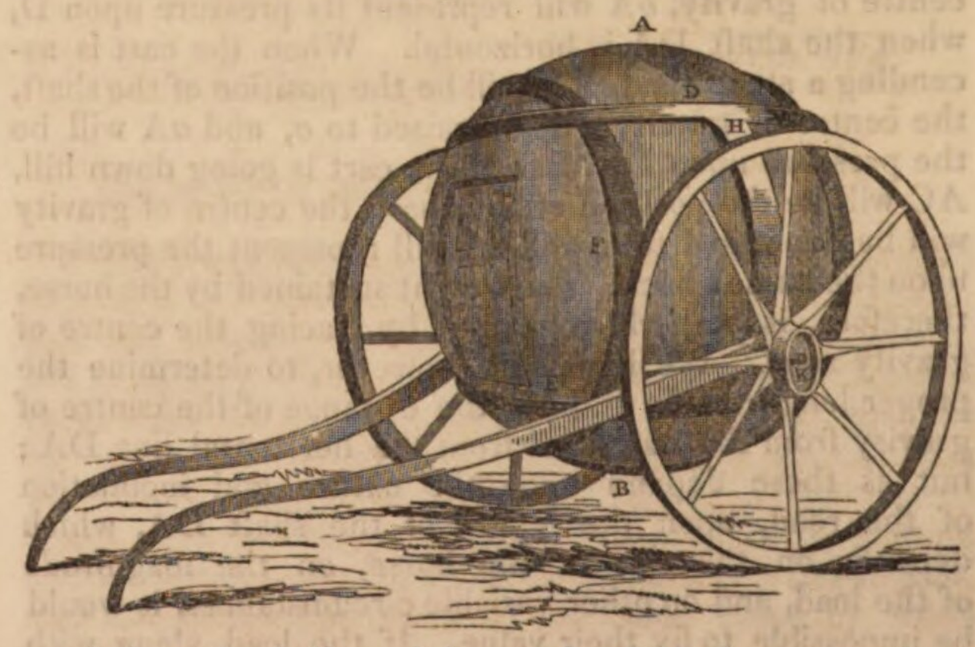
The carriage represented in fig. 150 is made so as to sail against the wind by means of the spiral sails E, F, G, H, one of which, F, is expanded by the wind. The impulse of the wind upon the sails gives a rotatory motion to the axle M, furnished with a cog-wheel K, whose trundles act upon teeth placed on the inside of the fore-wheels.

Fig. 150.



A carriage which cannot be overturned is represented in figure 151, where AB is the body of the carriage,

Fig. 151.



consisting of a hollow globe, made of leather or wood, at the bottom of which is placed an immoveable weight proportioned to the load which the carriage is to bear. Two horizontal circles of iron D, E, connected with bars HI, and two vertical circles F, G, surround the globe; and the wheels are fastened by a handle K to the perpendicular bars HI. Then, since the body of the carriage moves freely in every direction within the iron circles, the centre of gravity will always be near C, and the carriage will preserve an upright position even if the wheels and frame were overturned.

On Mechanical Notation.

PART III.—DESCRIPTION OF MACHINES.

As machines for various purposes in the arts have already been described in their appropriate places, we shall confine ourselves, in the present division of this article, to an account of Mr Babbage's mechanical notation; a description of the elements which enter into the composition of all machines; of machines which are illustrative of the general doctrines of mechanics; and of a few others which have not been described in any previous part of this work.

CHAP. I.—ON MECHANICAL NOTATION, OR THE METHOD OF EXPRESSING BY SIGNS THE ACTION OF MACHINERY.

Plate CCCXLVIII.

We have already given a general notice of this important method, invented by Mr Babbage, and pointed out its great importance in mechanics. We shall now endeavour to explain it more minutely, and show the method of applying it to a machine of a given structure. The first step in this method consists in drawing, on a sheet of paper, as many vertical lines as there are pieces or moving parts in the machine; to each of these pieces its name must be affixed, and the letter which marks it out in the drawing. These vertical lines must then be crossed with horizontal lines, upon which we must write,

1. The nature of the motion of each piece, indicated by a conventional sign.

2. The number of teeth in the wheels, pinions, or sectors, or the number of pins or studs on any revolving barrel.

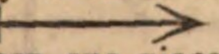
3. The velocities, whether absolute or relative, of the several parts of the machine.

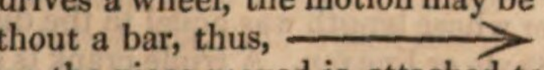
4. The mode in which the motion is communicated or transmitted.

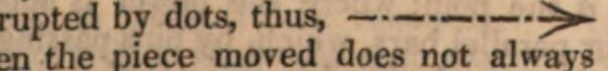
5. The modes of adjustment, some of which are permanent and made by the mechanist, while others depend on the nature of the work they are intended to perform, such as the distance between the mill-stones in a flour-mill, on which the fineness of the flour depends, or such as the winding up of the weight or spring, which may be called a periodic adjustment.

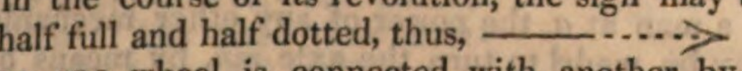
6. The times or durations of the movements.

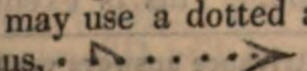
Mr Babbage employs two classes of signs, viz. those for indicating the peculiar nature of the means by which the motion is transmitted, and those which denote the state of motion or rest of every particular part of the machine. The first of those classes are as follows:

1. When one piece receives its motion from another, in consequence of being permanently fixed to it, such as a pin upon a wheel, or a wheel and pinion on the same axis. This may be indicated by an arrow with a bar at the end, thus, 

2. When one piece is moved by another, so that the motion of the one is the necessary result of the motion of the other, but without any permanent connection, as when a pinion drives a wheel, the motion may be indicated by an arrow without a bar, thus, 

3. When the piece moved is attached to the piece that moves it by stiff friction, the sign is an arrow formed by a line interrupted by dots, thus, 

4. When the piece moved does not always move with the piece that moves it, as in the case of a stent lifting a ball once in the course of its revolution, the sign may be an arrow half full and half dotted, thus, 

5. When one wheel is connected with another by a ratchet, as the great wheel of a clock is attached to the fusee, we may use a dotted arrow with a ratchet-hook at its end, thus, 

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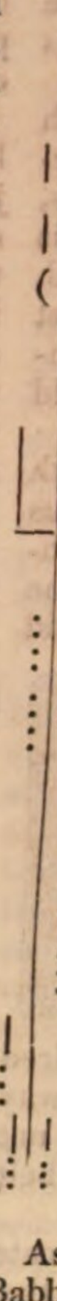
The second class of signs are as follows:



1. Unbroken lines indicate motion.

2. Lines on the right side indicate motion from right to left.

3. Lines on the left side indicate motion from left to right.

4. Parallel straight lines denote uniform motion.

5. Curved lines denote a variable velocity, and the ordinates of the curve should express the velocity.

6. When the motion begins at a fixed point, and its termination is uncertain, the line must begin with a small cross line.

7. When the commencement of the motion is uncertain, and its termination fixed, the line must end with a small cross line.

8. Dotted lines imply rest.

9. If the thing be indicated by a check, bolt, or valve, its dotted line should be on the right side if it is out of action, unbolted, or open, and on the left side if the reverse.

10. If a bolt can rest in three positions; 1*st*, bolted on the right side; 2*d*, bolted on the left side; 3*d*, unbolted; the figures are,

1. Bolted on the right side.

2. Bolted on the left side.

3. Unbolted, the two lines being nearer the indicating line.

As illustrations of the application of this method, Mr Babbage has selected the common eight-day clock and the hydraulic ram; but these examples are a little too complicated, especially that of the clock, which would require several plates to make it intelligible. We have therefore taken the case of an ideal but simple machine, which consists of a large wheel driving a system of levers and stampers, also a large beam driven by a crank. The motion is communicated by means of ropes. The system of signs is shown in Plate CCCXLVIII.

CHAP. II.—ON THE ELEMENTS OF MACHINERY.

The simple mechanical powers, which we have already fully described, are in reality machines or instruments by which useful mechanical effects are produced; but a *machine* is, properly speaking, a combination of the simple mechanical powers, arranged in such a manner as to produce the desired effect. The nature of this combination depends not only on the kind of mechanical agent which is to be the first mover, and on the nature of the work to be performed, but often on the locality of the machine itself, and other accidental causes; and the skill of the engineer is pre-eminently conspicuous in the adaptation of his machinery to these secondary conditions.

The principal elements of machinery are cylindrical and conical or bevelled wheels and pinions, and rack-work. When an axis is to receive motion from another axis lying parallel to it, the effect is produced by placing a *cylindrical* wheel upon each, as in fig. 104, so that half the sum of the diameters of the two wheels may be equal to the distance of the axes, and making the number of teeth in each wheel inversely proportional to the respective velocities

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which are required in the two axes. If the two axes are inclined to each other, then *conical* wheels are used, as shown in figs. 125, 126, and 128.

But it is not always necessary that the wheels move one another by means of teeth. In machines where the resistance of the work is trifling, one wheel may drive another by the mere *friction* of their circumferences. This may be done in several ways.

1. The circumference of the wheels may be faced with buff leather, the friction of which upon itself is considerable. We have seen this plan adopted in a pair of bellows, where the wind is propelled by a revolving vane which is driven by a winch and two intermediate wheels faced with buff. The circumferences of the wheels are pressed against each other by a spring, in order to maintain sufficient contact for the purpose. Rims made of caoutchouc would answer the purpose much better.

2. The circumference of the wheels may be faced with wood cut across the grain. Dr O. Gregory informs us that this plan was actually adopted in a saw-mill at Southampton, where all the wheels impelled one another by the contact of the end grain of the wood. The machine did its work with very little noise, and wore very well, having been in use for twenty years.

The same effect might be produced by putting a circumference of metal containing a great number of small blunt spikes or points upon the impelling wheel, and a rim of hard wood upon the other, upon which these blunt spikes act in turning it.

Belts and ropes.

When one wheel drives another, they necessarily turn in opposite directions. If it is required that they should move in the same direction, the best way is to unite them by a rope or leather belt which does not cross itself at any point between the wheels, for if the belt crosses, the wheels will move in opposite directions.

The great use of ropes or belts is to communicate motion from one axle to another, at such a distance that two wheels uniting the axles would be ridiculously large. In belts the motion is conveyed by friction. The friction between the impelling wheel and the belt puts the belt in motion, and the friction of the belt upon the impelled wheel moves it in the same manner.

The great disadvantage of ropes and belts however is, that they become slack, and thus lose their power of turning the wheel. This evil may be partially removed by increasing the friction by rubbing them with chalk, or, what is still better, by shortening them. Another method equally effectual, is to have upon one of the wheels grooves of different diameters, so that a slack belt may be tightened by slipping it upon a groove of larger diameter. This however alters the velocity of the axle upon which this change has been made;[1] and the only way to remove this evil, or to tighten a belt without altering the relative velocity of the two axles, is to have grooves of corresponding diameters on both wheels, so that the loose belt may be half tightened by shifting it to a groove of larger diameter on one wheel, and the tightening completed by shifting it also to a groove of larger diameter on the other wheel. The best method, however, of effecting the object in question would be to have one or more caoutchouc springs forming part of the belt.

Chains.

From these remarks it will be obvious, that in nice machinery, where regular movements are essential to its performance, or in cases where the work occasions a great strain upon the machinery, belts and ropes cannot with propriety or safety be employed. In such cases chains of various forms are substituted in their place. These chains are sometimes jointed like those of a watch, and convey the motion by friction; but in general it is necessary to adopt quite a different kind of chain, and to make them lay hold of pins or hooks projecting from the circumference which they put in motion. Two of these chains are shown in the annexed figures. In fig. 152 the links of the chain AC lay hold of the pins *p*, *p*, projecting from the circumference of the wheel DE.

Fig. 152.

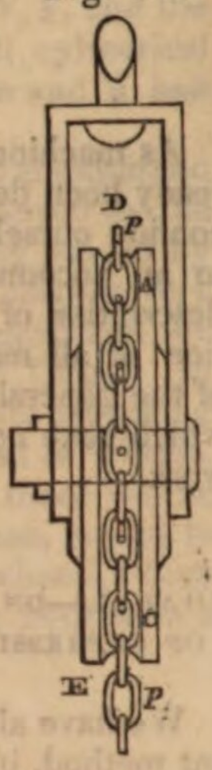

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Fig. 153.

In fig. 153, metallic teeth *t*, *t*, *t*, project from the jointed chain ABC, and enter into grooves or indentations in the circumference of the wheel. Various chains used in machinery are shown in the annexed figure. That marked A was invented and used by the great mechanist Vaucanson.

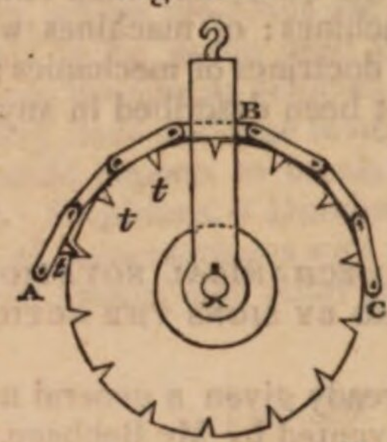
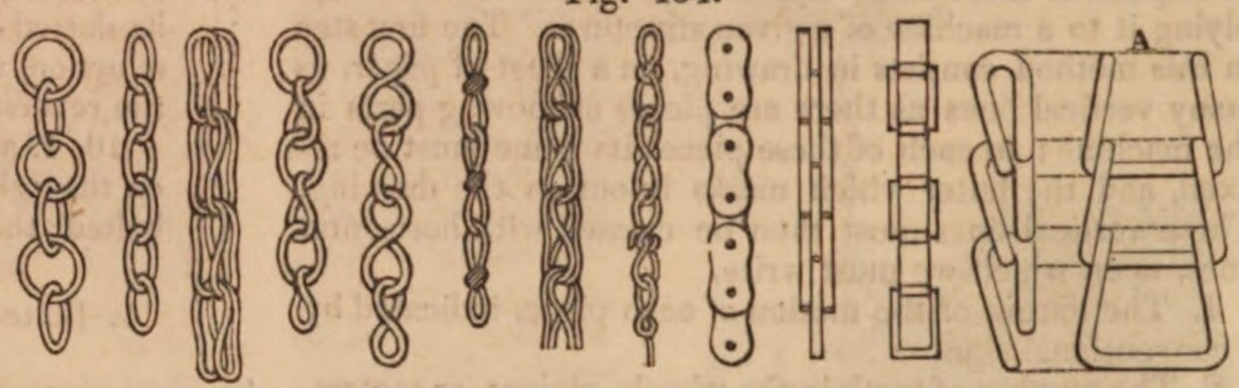


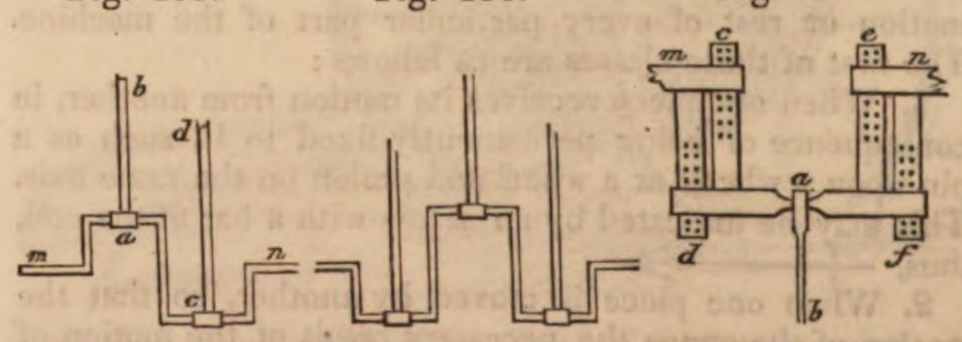
Fig. 154.



Crank.

One of the simplest and most durable expedients for communicating motion is the *crank*, which is nothing more than a lever fixed upon the axis, which is to be moved by a force applied to the end of the lever. This lever may be fixed at the end of the axis, as in the common grindstone, or in the electrical machine, where wheels are not used; or it may be fixed upon a wheel carried by the axle, when the object of the mechanism is to put a wheel in motion. This is the case in the old cylindrical electrical machines, where a handle is fixed upon the face of the largest wheel, employed to give velocity to the cylinder. The crank lever may be fixed in the middle of an axis; but in this case the axis must necessarily be bent, and the force applied at the part projecting from the axle, as shown in fig. 155, where *mn* is the axis bent

Fig. 155. Fig. 156. Fig. 157.



twice, at *a* and *c*, so as to form a double crank. Now if one man were to apply his force at *a* and another at *c*, they would work with a lever whose length was equal to the distance of *a* and *c* from the axle or line *mn*. A triple crank is shown at fig. 156; and a variable single crank in fig. 157 where *mn* is the axle, *a* the point where the power is applied, and *c*, *d*, *e*, *f*, four parallel bars, which, by pins passing through the small holes, may be fixed in any position, so as to vary the distance of *a* from *mn*. In place of applying the power of a man at *a*, the power of any other mechanical agent may be made to turn the axle *mn*, by means of rods *ba*, *dc*, fig. 155, &c. which have a reciprocating or a backward and forward rectilineal motion. This is exemplified in

[1] In a turning-lathe or an electrical machine, where a change of velocity does no harm, this contrivance answers very well.

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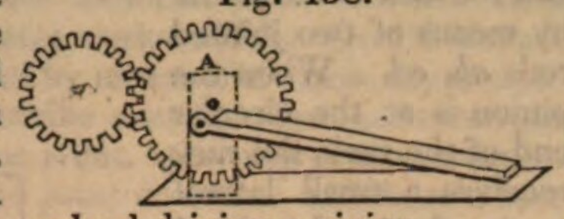
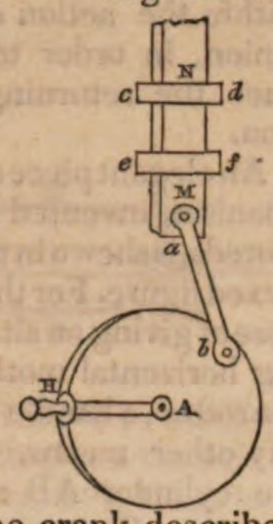
the grind-stone and the turning lathe, where the power is the downward pressure of the foot of a man upon a foot-board, as in fig. 158, where A may be a grindstone, or a wheel driving a pinion.

Fig. 158.



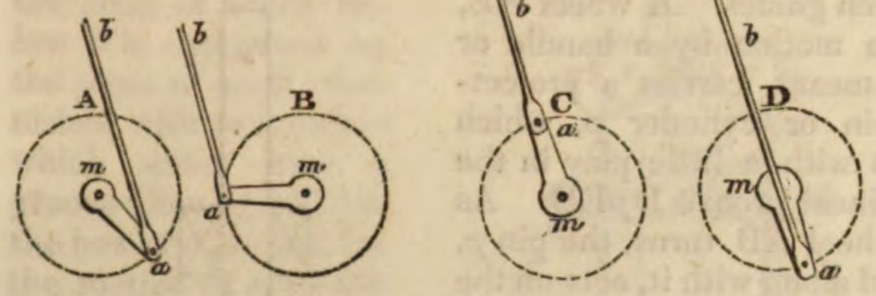
When the power applied at *a* is obtained from the reciprocating motion of a rod, as in the case of a steam-engine, it acts as in the annexed figure, where *b* is the crank fixed near the circumference of the wheel A, and MN a vertical rod moving upwards and downwards between the guides *cd*, *ef*, and connected with the crank by the bar *ab*.

Fig. 159.



When a man and a power moving in a fixed direction are applied to the same crank, the mode of action is in the two cases essentially distinct. In every mode of action both the man and the power push in one semicircumference of the circle, which the end of the crank describes, and pull in the other semicircumference; and it is very obvious, that in every position of the crank, both powers must act with different degrees of effect. When the crank lever is horizontal, and the man pushes it down with the aid of his weight, his force is a maximum; and when he pulls it upwards in the next horizontal position, his force is very great. At all intermediate positions he works to a disadvantage; but there are no positions of the crank in which the man has *no power to turn it*, because he is able to apply his power in any direction he chooses. This, however, is impossible when the man works by a vertical pressure, or a pressure given in direction upon a foot-board, or when the crank is moved by a reciprocating rod. In these cases, as will be seen at A, B, C, D in the annexed figures, there are two

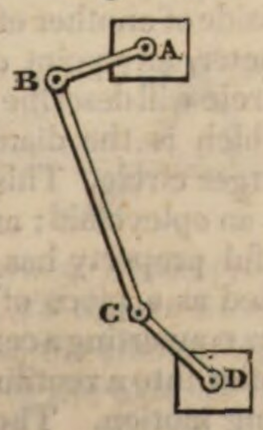
Fig. 160. Fig. 161. Fig. 162. Fig. 163.



opposite positions in which the rod has no power to move the crank. This happens in the positions C and D, where the centre *m* is between *a* and *b*, or when *a* is between *m* and *b*. In the other positions shown in the figures, the power of the rod *ba* to move the crank is proportional to the perpendicular let fall upon *ab* from the centre *m*; and when that perpendicular coincides with *ma*, or when *ma* is perpendicular to *ba*, the power is a maximum either in pushing or pulling the lever.

A combination of *two cranks* has been used for producing a high degree of pressure. This will be understood from the annexed figure, where the same lever BC unites two crank levers AB, CD, which move round joints or centres at A, B, C, and D. If we suppose a moving force applied to DC, to make it turn round D from right to left, it is obvious that the lever BC will be pulled in the direction BC with the greatest force, when BCD is a straight line. The force thus exerted acts upon the lever AB at B, and it will exert the greatest force when CB is perpendicular to BA. The force therefore originally applied to move CD will be very great when exerted at

Fig. 164.



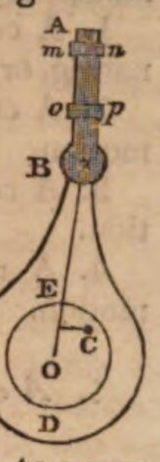
A. This combination of cranks is used in the Stanhope press, in which the axle C drives a screw, which presses the paper with great force upon the types.

On the Elements of Machinery.

Another contrivance similar in principle to the crank is frequently introduced into machinery. It is called the *Eccentric*, and is shown in fig. 165, where AB is a rod which is to be raised and depressed between the guides *mn*, *op*, by means of a continued circular motion. Let C be the centre of this circular motion, or a section of the revolving axis. Upon this axis C, is *fixed* a circle DE eccentric to it, O being its axis, and CO the degree of eccentricity. This circle DE works in a circular opening of the frame BED fixed to BA by a joint at B. As the axis C and the circle DE form one piece, and as C is fixed in position, the effect of turning the axis C must be to raise and depress BA between the guides, the power being always proportional, as in the crank, to a perpendicular let fall from C upon BD. When this perpendicular vanishes, which happens when the line CO coincides with BO, the rod A will be at its highest or its lowest point.

The eccentric.

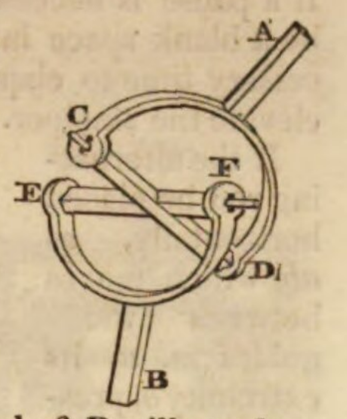
Fig. 165.



An ingenious contrivance for conveying motion is known by the name of *Hooke's Universal Joint*. The driving axis and the axis to be driven are shown at A, B. Each of them terminates in semicircles, joining two rectangular bars, CD, EF, by means of pivots at their extremities C, D, E, F. It is obvious that when A is made to revolve, B will revolve with the same velocity; for if A moves round without changing its direction, the points C, D must move in a circle round the intersection of the crossed bars, and this motion of the cross will make the points E, F move round the same intersection, in consequence of which the shaft B will revolve, the two shafts turning in the very same manner as if each had a pivot at the intersection, and were impelled with equal velocities. The one axis A will not drive the other B if their vertical inclination is less than 140.

Universal joint.

Fig. 166.



When the inclination of the axis is between 50° and 90°, a *double universal joint* is used, consisting of *four* semicircles and two crosses, and acting in the same manner as the other. It is shown in the annexed figure. Another form of the apparatus is shown in the annexed figure. Universal joints may be constructed by fastening *four* pins 90° from one another on the circumference of a hoop or solid ball.

Fig. 167.

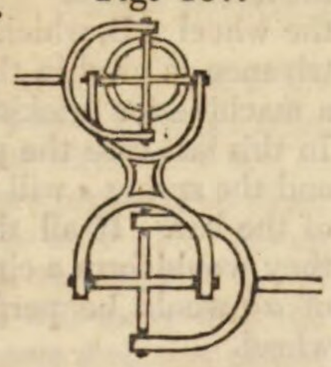
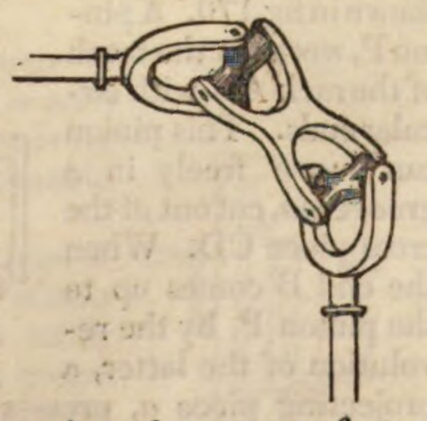


Fig. 168.



Universal joints are generally used in cotton-mills, where it is necessary to convey the motion through great distances. In this case it is advisable to divide the rods into lengths, and connect them by these joints. Universal joints are also much used in large telescopes upon equatorial axes, in order to give the vertical and horizontal motions to the tube while the observer continues to look through it.

Cam.

Another instrument for connecting the parts of machines is called the *Cam*, or *Camb*, or *Wiper*, and the general object of it is to convert a circular into a rectilineal motion. It is extensively used in the tambouring machinery, and in machines for making lace.

Contrivances for changing motion.

CHAP. III.—ACCOUNT OF CONTRIVANCES FOR CHANGING ONE KIND OF MOTION INTO ANOTHER.

The different changes of motion which are most useful in machinery may be classified as follows:—

1. A continued circular motion into a rectilineal, alternating, or vibrating motion.
2. A continued circular motion into a circular alternating motion.
3. A continued rectilineal into a continued circular motion.
4. A rectilineal alternating into a circular alternating motion.

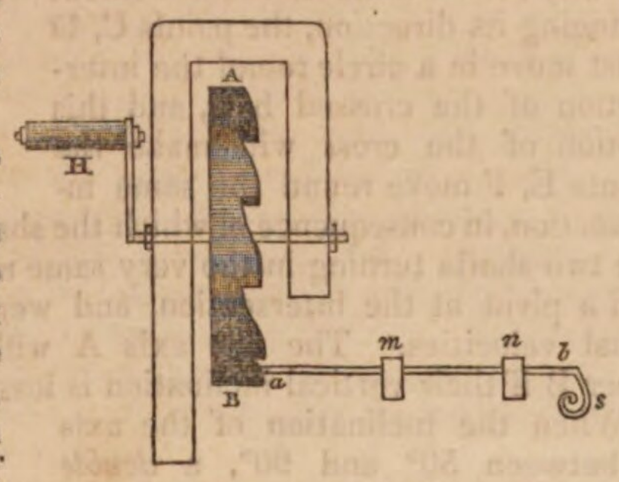
1. *A continued circular into a rectilineal alternating motion.*

The simplest of all the contrivances for this purpose is the *cam*, already referred to. The cam may have *one*, *two*, or *three*, or *more* wipers, according as we wish to have *one*, *two*, *three* or *more* alternations of the required motion during one revolution of the axis of the cam. If the alternating or vibrating rod stand vertically, it descends by its own weight, and is lifted by each succeeding cam. If a pause is necessary after each descent, then there must be a blank space in the revolving wheel, to allow the necessary time to elapse before the next cam come round to elevate the stamper.

Cam.

If the alternating rod be placed horizontally, as *ab*, which moves between the guides *m*, *n*, its extremity *b*, presses against the spring *s*, so as to push the rod back again upon the succeeding wiper, which is placed on the lateral face of the wheel AB, which is driven by a handle H. This contrivance is used in the manufacture or fishing nets, and in a machine for pricking holes in leather for making cards. In this last case the prickers will be placed at the end *b*, and the spring *s* will bear against some projecting shoulder of the bar. If all the teeth in AB were reduced to *one*, they would form a circular inclined plane, and one vibration of *ab* would be performed during each revolution of the wheel.

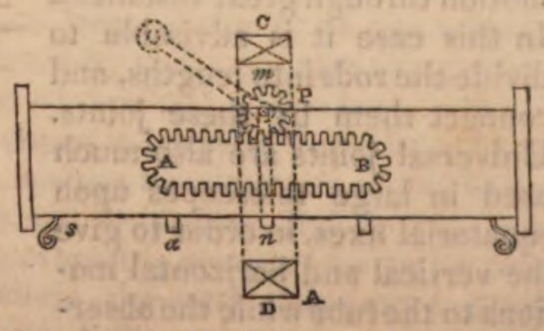
Fig. 169.



Pinion and double rack.

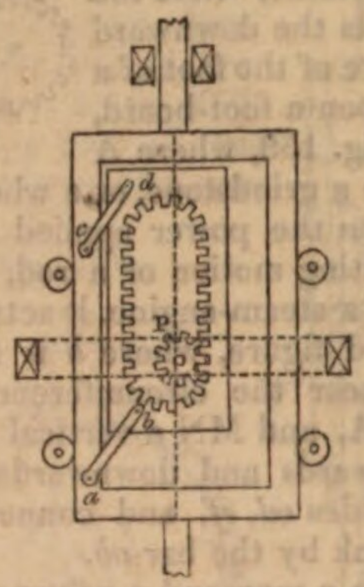
Another contrivance for this purpose, namely, a *double rack and pinion*, is shewn in fig. 170. A pinion P, works in the teeth of the rack AB, with circular ends. This pinion can move freely in a groove *mn*, cut out of the cross piece CD. When the end B comes up to the pinion P, by the revolution of the latter, a projecting piece *a*, presses against the spring *s*; and the pinion descending in the groove *mn*, enters the lower side of the rack, and carries it back, so that an alternating rectilineal motion is maintained.

Fig. 170.



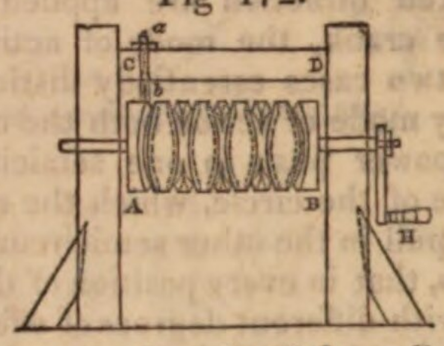
Another ingenious contrivance ot the same kind is shewn in the annexed figure. In this case the pinion P, is fixed, and the rack is moveable by means of two jointed rods *ab*, *cd*. When the pinion is at the circular end of the rack, the rack receives a small lateral motion from *a b* and *c d*, which brings forward the other side of the rack within the action of the pinion, in order to produce the returning motion.

Fig. 171.



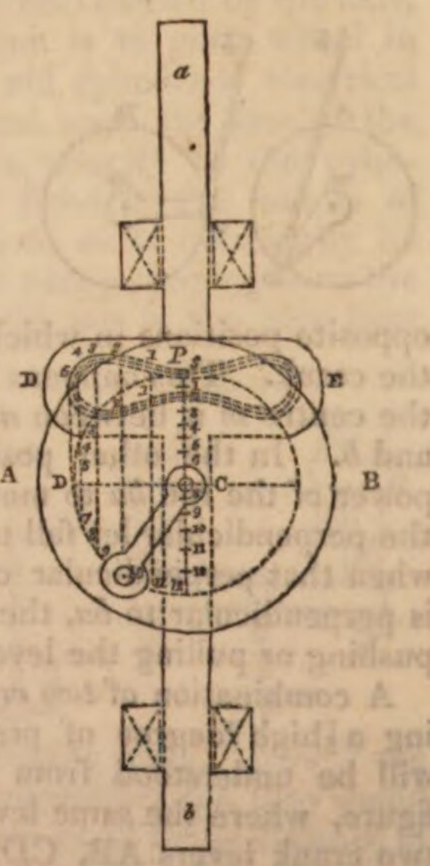
An elegant piece of mechanism, invented by M. Zureda, is shewn in the annexed figure. For the purpose of giving an alternating horizontal motion to the rod *ab*, a handle H, or any other means, turns the cylinder AB round its axis. Two opposite grooves, like the threads of a female screw, are cut in its surface, so as to unite or run into one another at both ends of the cylinder. The end *b* of the rod *ab*, fits this groove, while the end *a* moves up and down in a groove in the frame CD. As the cylinder revolves, the end *b* follows the spiral direction of the groove, till it reaches the end B, and it then enters the opposite groove, by which it returns to its original place, as in the figure. If a cone be substituted for the cylinder, the path of *ab* or the degree of its inclination to the revolving axis, is determined by the angle of the cone.

Fig 172.



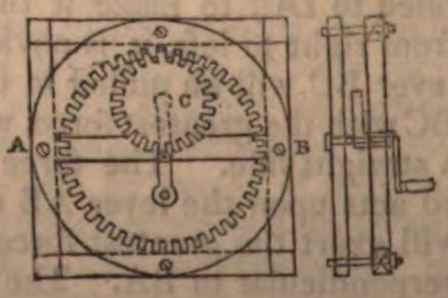
Another contrivance for producing a vertical alternating motion is shewn in fig. 173, where *ab* is a rod moving vertically between guides. A wheel AB, put in motion by a handle or other means, carries a projecting pin or cylinder *p*, which moves with a little play in the curvilineal groove D*p*ED. As the wheel AB turns, the pin *p*, carried along with it, acts on the under side of the curve, and depresses the rod; and when the pin *p* has reached its lowest point, it begins to raise the rod *ab*, by acting on the upper side D*p*E of the groove. If the groove DE had been a straight line, the ascent or descent of *ab* would have been variable, being equal to the versed sine of the arch described by the wheel.

Fig. 173.



When a circle revolves in the inside of another of *twice* the diameter, any point of the smaller circle will describe a straight line, which is the diameter of the larger circle. This straight line is an epicycloid; and this beautiful property has been embodied as a piece of mechanism, for converting a continuous circular into a rectilineal alternating motion. The mechanical expression of the geometrical property is shewn in fig. 174,

Fig. 174.

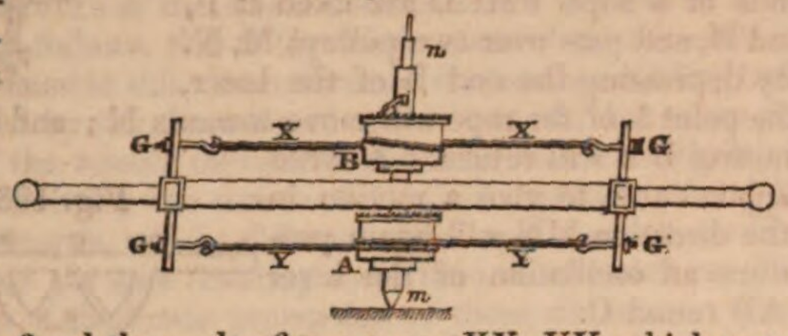


Contrivances for changing motion.

where AB is a concave toothed wheel, in which another wheel of half its diameter works. If the wheel C is made to revolve within the other by means of a winch, any point in its circumference will describe a straight line, and consequently any rod fixed to that point, and lying in the direction of the diameter which the point describes, will have a rectilineal alternating motion.

The ingenious method of M. Berthelot of obtaining a continued circular from an alternating motion is shewn in fig. 175. The alternating motion is communicated from the frame GGGG, to hooks in which are fixed the ends of two ropes XX, YY, which pass round the two wheels A, B, which move freely on the axis *mn*, in one direction, but carry the axis along with them in another direction. This is effected by ratchet wheels and clicks, one of which is placed on the inner side of A, and the other on the outer side of B. By moving the frame to the right, the wheel A being unable to move upon the axis *mn*, carries it round with it, and by moving the frame to the left, the wheel A being no longer fixed by the click and ratchet turns freely on the axle *mn*, but the other B being now locked to the axle, carries the axle *mn* along with it, and in the same direction as the wheel A did, so that the axle *mn* then receives a continued rotatory motion from the reciprocation of the frame GG.[1]

Fig. 175.



M. Betancourt's machine for converting continuous circular motions into rectilineal alternating motions *of a given length*, is shewn in the annexed figure, where *ab* is the revolving axis, the pivot of which below *b* is supported by the piece of wood *e* furnished with two rollers which enter into a groove (See fig. 177.) in the box *m'n'*, so that by the motion of *e* to the right or the left, the axis *ab* can approach one after another to the toothed wheels F, G, and drive them by the endless screw *h*. Two clicks *a'b' cd*, turning round their axes *a'* and *c* are fixed to *e*, and these clicks carry two arms *b'* and *d* perpendicular to them. A metallic bar *mn* (fig. 177), with a rectangular branch *u* is fixed at the end of an axis *gf*, which carries a double fork *il*; at the end *g* of the axis *gf*, is fixed a counterweight P. Two square pins *xy*, whose projection is equal in thickness to the clicks *a'b' cd*, are fixed in the box *m'n'*. Let us now suppose that the alternating motion to be obtained from the rotation of the axis *ab* is

Fig. 176.

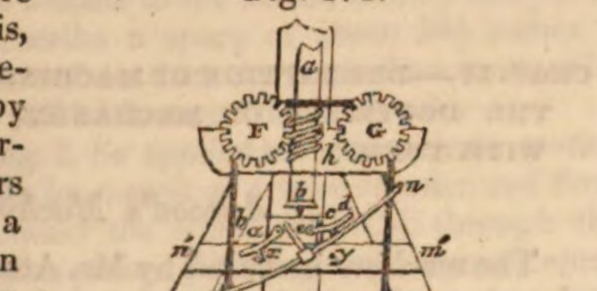
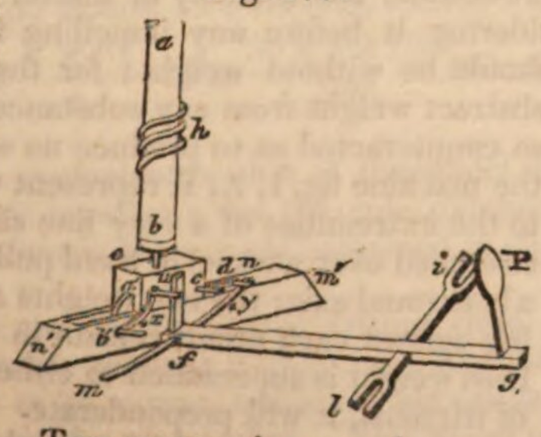


Fig. 177.



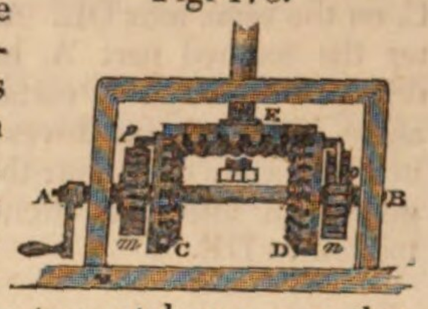
that of two buckets (one of which is seen at S, fig. 176, the other being down in the well), suspended at the extremities of a rope passing over the cylindrical portion of the two wheels F, G, and coiled once round each. The action of the machine will be as follows: When the branch *u* has pushed the click *a'* to the left as in fig. 176, the endless screw *h* being brought into action with F drives it round, and the click *a'b'* falling by its gravity, engages with the pin *x*, and presses the axis *ab* against the toothed wheel. The rope FS passes through the fork *l*, and when a button *s* upon the rope near S is engaged in the fork *l*, the piece *umn* is made to turn about its axis *fg*, and the arm *m* striking the handle *b*, unlocks the click *a'b'* before taking a horizontal position. But as soon as it passes this position the counterweight P falling on the other side, the branch *u* pushes the pin *c*, and carries to the right hand the axis *ab* which carries the endless screw *h* to engage itself with the wheel G, the click *cd* by its own weight engaging with the pin *y*. In this way the two cylinders behind F and G turn with these wheels in opposite directions, and the bucket S descends while the other ascends. A piece of iron is placed on the rims of the buckets to make them take a position for discharging the water as at S. The axis *ab* may be driven by wind or any other power.[2]

Contrivances for changing motion.

2. *A continued circular into an alternating circular motion, or the reverse.*

A very ingenious piece of mechanism for converting an alternating circular into a continued circular motion, is shewn in the annexed figure. The axis AB is made to move as if driven by a pendulum swinging at A. This axle carries two ratchet wheels *m n* with their teeth oppositely inclined, and also two bevelled tooth wheels C, D, which are however only slightly fixed to it by friction. These last wheels carry two catches *p*, *q*, so that when one or other falls into the teeth of the ratchet wheels *m*, *n*, this wheel moves round along with the axis, while the other wheel, which is not connected with its catch, moves round by any force greater than its friction. The bevelled wheel E, which is to receive a continued circular motion, is engaged by its teeth both in C and D.

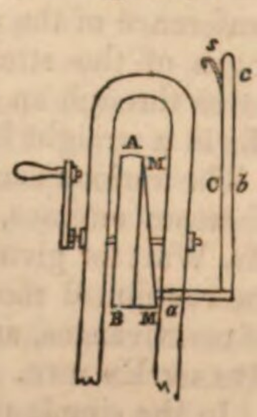
Fig. 178.



If we suppose the axis AB to swing so that *m* and C are fixed by the catch *p*, the wheel C will turn with the axle, and the wheel E will move in the same direction; and as the teeth on the right hand side of E are engaged on those of D, the latter will turn round upon the axle AB. When AB returns, or its motion is reversed, the teeth of *n* will move against the catch *q*, the wheel D will move with the axle AB, and E will be driven in the same direction as before, the wheel C now moving loosely upon AB. By changing the place of the ratchet wheel and catches, the motion of E would be reversed.

Another example of the change of motion under our consideration is seen when wipers fixed upon a revolving wheel raise a forge hammer moveable about a centre.

Fig. 179.



Another contrivance of this kind is shewn in the annexed figure, where AB is a one toothed wheel, the tooth being an inclined plane winding round its axis. This plane presses against the extremity *a* of a crooked lever *abc*, and gives it an alternating circular motion

[1] See Borgnis *Essai*, &c. p. 370.

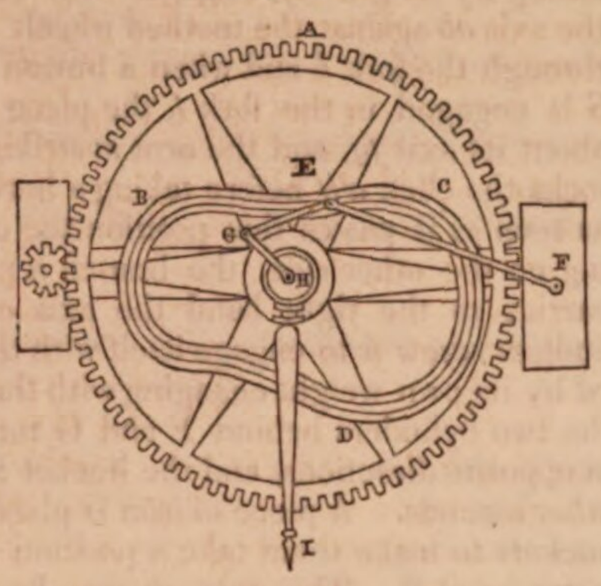
[2] Lanz and Betancourt's *Essai sur le Composition des Machines*, p. 82, 83.

Contrivances for changing motion.

round the centre C, a spring *s* occasioning the return of the lever to receive a new impulse from the revolving plane. By loading the arm *cba* the lever would return by the action of gravity alone.

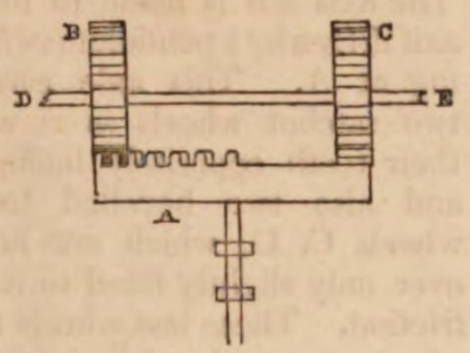
M. St. Cyr has produced an alternating circular motion, so that the velocity may vary according to any required law by the mechanism in fig. 180; and he has employed the principle used in the construction of equation clocks. An equation curve BCD is fixed on the annual wheel A, and in the curve is formed a groove in which the pivot E can move. This pivot is united with the levers EF, EG, the last being fixed to the cannon H which carries the minute hand HI, so that it follows the vibration of the curve in more than one half of the circumference of the minute dial which is sufficient to mark the inequalities arising from the equation.[1]

Fig. 180.



Another pretty contrivance is shewn in fig. 181, where A, a wheel partly toothed drives two toothed wheels B, C, on the same axis DE. After the toothed part A has driven B through a certain angle, it quits it and drives C in the opposite direction; thus giving an alternate circular motion to DE.

Fig. 181.



3. *A continued rectilineal into a continued circular motion.*

This change of motion is easily effected by means of a rectilineal rack acting upon a toothed wheel; but the continued circular motion of the wheel must terminate when it has made as many revolutions as the number of teeth in the wheel are contained in the number of teeth in the rack.

4. *A rectilineal alternating into a circular motion, or the reverse.*

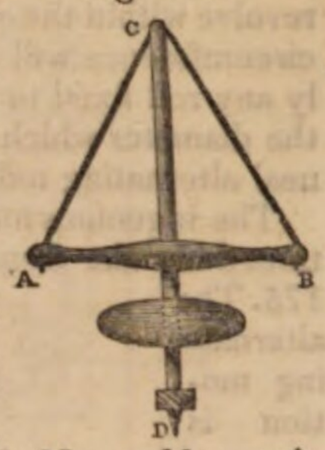
This change of motion is exemplified in the drill-bow of watchmakers and smiths, and in the handles of pumps. In the first the rectilineal alternating motion of the bow gives a circular alternating motion to an axle round which the bow-string is coiled. The extent of angular motion of the axle is determined by the number of times that the circumference of the pulley upon the axle is contained in the length of the stroke of the bow. In pumps the handle moves through an arch of a circle when the piston rises or falls in a straight line.

The various contrivances used by the early constructors of steam engines, and the more elegant ones invented by Mr. Watt for giving an alternating motion to the beam by the rectilineal movements of the piston belong to this class of contrivances, and will be fully described under the article Steam Engine.

In the simple piece of mechanism shewn in fig. 182; the bar AB attached to the axis C by two ropes AC, BC rises and falls by giving it a circular motion which twists the ropes, and makes it rise towards C. In untwisting them by the opposite motion of AB the bar descends. A drill D may thus be put in motion.

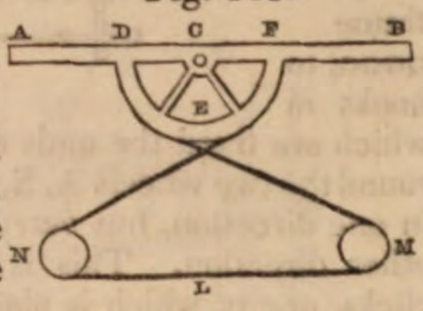
Contrivances for changing motion.

Fig. 182.



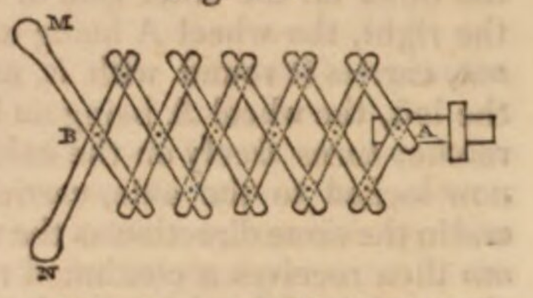
The mechanism shewn in fig. 183 produces an analogous effect. The lever AB vibrates round C as a centre. The ends of a rope FMLD are fixed at F, and D, and pass over two pulleys M, N. By depressing the end B of the lever, the point L of the rope will move towards N; and by again raising B it will return. A force applied at L to give a motion in the direction MN will again produce an oscillation of the lever AB round C.

Fig. 183.



A combination of levers called *zig-zag*, or *lazy tongs*, or *scissors*, shewn in fig. 184, is of the same kind. Joints being placed at the intersection of all the pieces which compose it, it is evident that if the ends MN open or shut by a circular motion, the points A, B will approach to, or recede from, one another.[2] These *lazy tongs* are ingeniously applied by Mr. Aldous of Clapton, for conveying the motion of the beam of his steam engine to the crank which gives the circular motion. See the *London Journal*, or *Repertory of Arts*, No. 55, Oct. 1836, p. 57.

Fig. 184.



CHAP. IV.—DESCRIPTION OF MACHINES WHICH ILLUSTRATE THE DOCTRINES OF MECHANICS, OR ARE CONNECTED WITH THEM.

Atwood's Machine.

The machine invented by Mr. Atwood for illustrating the doctrines of accelerated and retarded motion, is represented in figs. 1, 2, 3, 4, 5, 6, Plate CCCXLIX., and enables us to discover, 1st, the quantity of matter moved; 2d, the moving force; 3d, the space described; 4th, the time of description; and, 5th, the velocity acquired at the end of that time. Atwood's machine. Pl. CCCXLIX

1. *Of the quantity of matter moved.*—In order to observe the effects of the moving force, which is the object of any experiment, the interference of all other forces should be prevented; the quantity of matter moved, therefore, considering it before any impelling force has been applied, should be without weight; for though it be impossible to abstract weight from any substance whatever, yet it may be so counteracted as to produce no sensible effect. Thus, in the machine fig. 1, A, B represent two equal weights affixed to the extremities of a very fine silk thread; this thread is stretched over a wheel or fixed pulley *abcd*, moveable round a horizontal axis: the two weights A, B being equal, and acting against each other, remain in equilibrio; and when the least weight is superadded to either (setting aside the effects of friction), it will preponderate. When AB are set in motion by the action of any weight *m*, the sum A + B + *m*, would constitute the whole mass moved, but for the inertia of the materials which must necessarily be used in the communication of motion. These materials consist of, 1st, the

Fig. 1.

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[1] See *Machines Approuvées par l'Academie*, tom. iii. No. 146; tom. iv. No. 235, 269, 278; tom. viii. No. 488, 495.

[2] Ibid. tom. vi. No. 429. Borgnis *Essai*, &c. p. 163, 169.

Description of Machines.

wheel *abcd*, over which the thread sustaining A and B passes; 2d, the four friction wheels on which the axle of the wheel *abcd* rests; 3d, the thread by which the bodies A and B are connected, so as when set in motion to move with equal velocities. The weight and inertia of the thread are too small to have any sensible effect on the experiments; but the inertia of the other materials constitute a considerable proportion of the mass moved, and must therefore be taken into account. Since, when A and B are put in motion, they must move with a velocity equal to that of the circumference of the wheel *abcd* to which the thread is applied; it follows, that if the whole mass of the wheels were accumulated in this circumference, its inertia would be truly estimated by the quantity of matter moved; but since the parts of the wheels move with different velocities, their effects in resisting the communication of motion to A and B, by their inertia, will be different; those parts which are furthest from the axis resisting more than those which revolve nearer in a duplicate proportion of those distances. (See ROTATION.) If the figures of the wheels were regular, the distances of their centres of gyration from their axis of motion would be given, and consequently an equivalent weight, which being accumulated uniformly in the circumference *abcd*, would exert an inertia equal to that of the wheels in their constructed form, would also be given. But as the figures are irregular, recourse must be had to experiment, to assign that quantity of matter, which being accumulated uniformly in the circumference of the wheel *abcd*, would resist the communication of motion to A in the same manner as the wheels.

In order to ascertain the inertia of the wheel *abcd*, with that of the friction wheels, the weights AB being removed, the following experiment was made:—

A weight of thirty grains was affixed to a silk thread of inconsiderable weight; this thread being wound round the wheel *abcd*, the weight thirty grains, by descending from rest, communicated motion to the wheel, and by many trials was observed to describe a space of about $38\frac{1}{2}$ inches in three seconds. From these data the equivalent mass or inertia of the wheels will be known from this rule.

Fig. 2. Let a weight P, fig. 2, be applied to communicate motion to a system of bodies by means of a very slender and flexible thread going round the wheel SLDIM, through the centre of which the axis passes, (G being the common centre of gravity, R the centre of gravity of the matter contained in this line, and O the centre of oscillation). Let this weight descend from rest through any convenient space s inches, and let the observed time of its descent be t seconds; then if l be the space through which bodies descend freely by gravity in one second, the equivalent weight sought $= \frac{W \times SR \times SO}{SD^2} = \frac{P \times t^2 l}{s} - P$.

Here we have $p=30$ grains, $t=3$ seconds, $l=193$ inches, $s=38.5$ inches; and $\frac{P \times t^2 l}{s} - P = \frac{30 \times 9 \times 193}{385}, 30 = 1322$ grains, or $2\frac{3}{4}$ ounces.

This is the inertia equivalent to that of the wheel *abcd*, and the friction wheels together; for the rule extends to the estimation of the inertia of the mass contained in all the wheels.

The resistance to motion, therefore, arising from the wheel's inertia, will be the same as if they were absolutely removed, and a mass of $2\frac{3}{4}$ ounces uniformly accumulated in the circumference of the wheel *abcd*. This being premised, let the boxes A and B be replaced, being suspended by the silk thread over the wheel or pulley *abcd*, and balancing each other; suppose that any weight m, be added to A, so that it shall descend, the exact quantity of matter moved, during the descent of the weight A, will be ascertained, for the whole mass will be $A+B+m+2\frac{3}{4}$ oz.

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In order to avoid troublesome computations in adjusting the quantities of matter moved and the moving forces, some determinate weight of convenient magnitude may be assumed as a standard; to which all the others are referred. This standard weight in the subsequent experiments is a quarter of an ounce, and is represented by the letter m. The inertia of the wheels being therefore $=2\frac{3}{4}$ ounces, will be denoted by $11\ m$. A and B are two boxes constructed so as to contain different quantities of matter, according as the experiment may require them to be varied; the weight of each box, including the hook to which it is suspended $=1\frac{1}{2}$ oz., or, according to the preceding estimation, the weight of each box will be denoted by $6\ m$; these boxes contain such weights as are represented by fig. 3, each of which weighs an ounce, so as to be equivalent to $4\ m$; other weights of $\frac{1}{2}$ oz. $=2\ m$, $\frac{1}{4}=m$, and aliquot parts of m, such as $\frac{1}{2}\ m$, $\frac{1}{4}\ m$, may be also included in the boxes, according to the conditions of the different experiments hereafter described. Fig. 3.

If $4\frac{3}{4}$ oz. or $19\ m$, be included in either box, this, with the weight of the box itself, will be $25\ m$; so that when the weights A and B, each being $25\ m$, are balanced in the manner above represented, their whole mass will be $50\ m$, which being added to the inertia of the wheels $11\ m$, the sum will be $61\ m$. Moreover, three circular weights, such as that which is represented at fig. 4, are constructed, each of which $=\frac{1}{4}$ oz., or m; if one of these be added to A and one to B, the whole mass will now become $63\ m$, perfectly in equilibrio, and moveable by the least weight added to either, (setting aside the effects of friction), in the same manner precisely as if the same weight or force were applied to communicate motion to the mass $63\ m$, existing in free space and without gravity.

2. *The moving force.*—It will be convenient here to apply a weight to the mass A as a moving force. When the system consists of a mass $=63\ m$, according to the preceding description, the whole being perfectly balanced, let a weight $\frac{1}{4}$ oz., or m, such as is represented in fig. 5, be applied on the mass A; this will communicate motion to the whole system; by adding a quantity of matter m to the former mass $63\ m$, the whole quantity of matter moved will now become $64\ m$; and the moving force being $=m$, this will give the force which accelerates the descent of $A = \frac{m}{64\ m}$, or $\frac{1}{64}$ part of the accelerating force of gravity. Fig. 5.

By the preceding construction, the moving force may be altered without altering the mass moved; for suppose the three weights m, two of which are placed on A and one on B, to be removed, then will A balance B. If the weights $3\ m$ be all placed on A, the moving force will become 3 m, and the mass moved $64\ m$ as before, and the force which accelerates the descent of $A = \frac{3\ m}{64\ m} = \frac{3}{64}$ parts of the force by which gravity accelerates falling bodies.

Suppose it were required to make the moving force $2\ m$, the mass moved continuing the same. Let the three weights, each of which $=m$, be removed; A and B will balance each other; and the whole mass will be $61\ m$; let $\frac{1}{2}\ m$, fig. 5, be added to A, and $\frac{1}{2}\ m$ to B, the equilibrium will be preserved, and the mass moved will be $62\ m$; now let $2\ m$ be added to A, the moving force will be $2\ m$, and the mass moved $64\ m$ as before; wherefore the force of acceleration $=\frac{1}{32}$ part of the acceleration of gravity. Fig. 5.

3. *Of the space described.* The body A, fig. 1, descends in a vertical line; and a scale about sixty-four inches in length divided into inches and tenths of an inch is adjusted vertical, and so placed that the descending weight A may fall in the middle of a square stage, fixed to receive it at the end of the descent; the beginning of the descent is esti- Fig. 1.

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mated from 0 on the scale, when the bottom of the box A is on a level with 0. The descent of A is terminated when the bottom of the box strikes the stage, which may be fixed at different distances from the point 0; so that by altering the position of the stage, the space described from rest may be of any given magnitude less than sixty-four inches.

4. *The time of description* is observed by a seconds pendulum; and the experiments may be so constructed that the time of motion shall be a whole number of seconds. The estimation of the time, therefore, admits of considerable exactness, provided the observer takes care to let the bottom of the box A begin its descent precisely at any beat of the pendulum; then the coincidence of the stroke of the box against the stage, and the beat of the pendulum at the end of the time of motion, will show how nearly the experiment and the theory agree. There might be various devices for letting the weight A begin its descent at the instant of a beat of the pendulum W; for instance, let the bottom of the box A, when at 0 on the scale, rest on a flat rod, held in the hand horizontally; its extremity being coincident with 0, by attending to the beats of the pendulum; and with a little practice, the rod which supports the box A may be removed at the moment the pendulum beats, so that the descent of A shall commence at the same instant.

5. *Of the velocity acquired.* It remains only to describe in what manner the velocity acquired by the descending weight A, at any given point of its path is made evident to the senses. The velocity of A's descent being continually accelerated will be the same in two points of the space described. This is occasioned by the constant action of the moving force; and since the velocity of A at any instant is measured by the space which would be described by it moving uniformly for a given time with the velocity it had acquired at that instant, this measure cannot be experimentally obtained, except by removing the force by which the descending body's acceleration was caused.

In order to shew in what manner this is effected particularly, let us again suppose the boxes A and B$=25m$ each, so as together to be $=50m$; this with the wheel's inertia $11m$ will make $61m$; now let m be added to A, and an equal weight m to B. these bodies will balance each other, and the whole mass will be $63m$. If a weight m be added to A, motion will be communicated, the moving force being m, and the mass moved $64m$. In estimating the moving force, the circular weight $=m$ was made use of as a moving force; but for the present purpose of showing the velocity acquired it will be convenient to use a flat rod, the weight of which is also $=m$. Let the bottom of the box A be placed on a level with 0 on the scale, the whole mass being as described above $=63m$, perfectly balanced. Now let the rod, the weight of which $=m$, be placed on the upper surface of A; this body will descend along the scale in the same manner as when the moving force was applied in the form of a circular weight. Suppose the mass A, fig. 5. to have descended by constant acceleration of the force of m, for any given time, or through a given space: let a circular frame be so affixed to the scale, contiguous to which the weight descends, that A may pass centrally through it, and that this circular frame may intercept the rod m by which the body A has been accelerated from rest. After the moving force m has been intercepted at the end of the given space or time, there will be no force operating on any part of the system which can accelerate or retard its motion; this being the case, the weight A, the instant after m has been removed, must proceed uniformly with the velocity which it had acquired that instant: in the subsequent part of its descent, the velocity being uniform will be measured by space described in any convenient number of seconds.

This machine is useful for estimating the velocities communicated by the impact of elastic and nonelastic bodies; the resistance opposed by fluids, as well as for various other purposes. It may be necessary to show in what manner the motion of bodies resisted by constant forces are reduced to experiment by this machine. Suppose the mass contained in the weights A and B, fig. 5, and the wheels to be 61 m, when in equilibrio; let a weight m be applied to B, and let two long weights or rods, each $=m$, be applied to A, then will A descend by the action of the moving force m, the mass moved being $64m$; suppose that when it has described any given space by constant acceleration, the two rods m are intercepted by the circular frame above described, while A is descending through it, the velocity acquired by that descent is known; and when the two rods are intercepted, the weight A will begin to move on with the velocity acquired, being now retarded by the constant force m; and since the mass moved is 62 m, the force of retardation will be $\frac{1}{62}$ part of that force whereby gravity retards bodies thrown perpendicularly upwards. The weight A will therefore proceed along the graduated scale in its descent, with an uniformly retarded motion, and the spaces described, times of motion, and velocities destroyed by the resisting force, will be subject to the same measures as in the examples of accelerated motion.

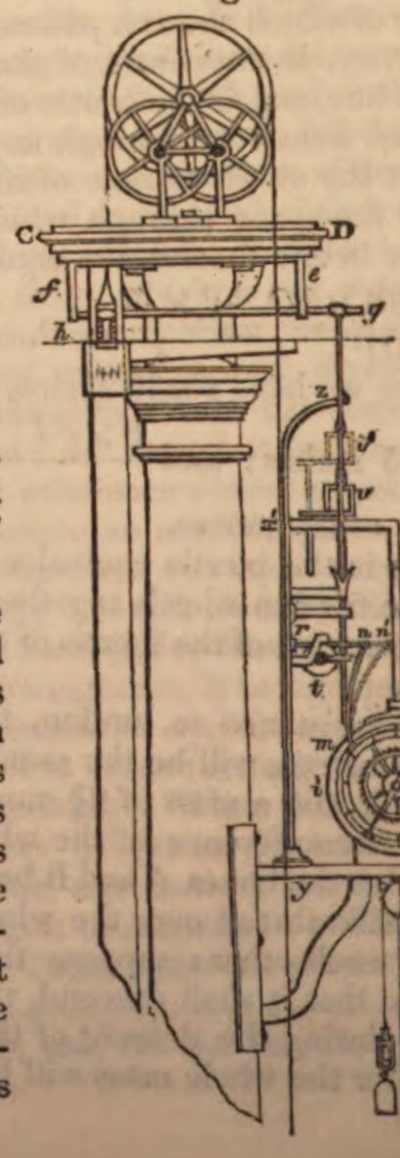
In this description, three suppositions have been assumed, which though *physically* are not *mathematically* true.

1. It has been assumed that the force which communicates motion to the system, is constant, which is true only when the line which suspends the weights A and B is without weight. The effect of the string's weight, however, is so trivial that if, in a particular case, we calculate the time of descent we shall find it to be 3.9896 seconds; and when the string's weight is considered, 4.0208 seconds, giving a difference of only three hundredths of a second, which is unappreciable by observation.

2. It has been also supposed that the bodies move in vacuo, but as the greatest velocity is only 26 inches in a second, the time of descent cannot be increased by the air's resistance, the two hundred and fortieth part of the whole.

3. The machinery has been supposed without friction, but the effect of the friction is such that $1\frac{1}{2}$ grains will destroy the equilibrium of the weights A and B. In experiments, on retarded motion, where friction does become sensible, it may be corrected by adding $1\frac{1}{2}$ or 2 grains to the descending body, or a little more than will destroy the equilibrium of A and B.

Fig. 185.



In constructing one of these machines for the Faculty of Sciences at Paris, Mr. Fortin has made a considerable improvement upon it by adding a detent for causing the weight A to begin its descent at the instant that the second's hand marks 0″ on the dial plate.

This contrivance will be understood from the annexed figures. Two pillars of brass e, f fixed beneath the platform CD support a horizontal axis gh perpendicular to two arms of a lever, one of which is larger than the other, the use of the shortest being to support the weight A in its first position. (See fig. 186.) The longer lever being at first detained by a catch, disengages

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itself and makes the axis *gh* turn. The short lever turning at the same time leaves its first position, and the weight A, no longer sustained by the short lever, begins to move. In fig. 186, which is a section at right angles, to *gh* the axis *gh* is projected into *g*. The short and long levers *gh*, *gk* are shewn by the dotted lines as in their first position the first is sustaining A, and in their second position by *gl'*, *gk'* the end *k* of the larger one having descended to *k'* and being detained at *k'* by a fork.

The disengagement of the end *k* of the long lever *gk* at the instant of the second's hand pointing to *zero* in the time-plate is thus effected. A lever with two arms is fixed on a horizontal axis attached to the platform which supports the pendulum. The inner arm of this lever *im* is held by the plate, and the outer one *mnr* consisting of two branches *mn*, *nr* united by a joint or pivot about which the branch *mn* may turn. The other branch *nr*, which is a flat surface, can move only horizontally in the groove of a pulley *t*. A vertical iron rod *v*, *v'* is capable of taking these two positions corresponding to the two positions of the moveable plate *nr*. In the first position *v* it passes through a cut out part of the plate *nr*, and in the second position *v'* its extremity bears against the full or uncut part of the branch *nr*. In the position *v'* of the rod the end *k* of lever *gk* is engaged in the fork *v'* at the end of the rod. A wiper, seen in fig. 186, fixed to the toothed wheel of the pendulum acts upon the end *i* of lever *mi*. The joint *n* takes the position *n'* fig. 185; the branch *nr* slides horizontally in the same direction, and *o'*, no longer supported by the uncut part of *nr*, falls through the part that is cut out and takes the position *v* when it is stopped by a horizontal rod *xx'* fixed between the upright bars P*x*, *yx'z*, the one rising from the pendulum box P, and the other from a shelf *y* below the pendulum. For the purpose of bringing the end *k'* of the lever *gk'* into the fork *v* of the vertical rod, a thread attached to *k* passes first through the fork, and next through an eye *z* of the bent part of the rod *yx'z*. Another thread goes to the same eye from the fork, and by successively drawing these two threads the plate *nr* is pushed at the end *r* towards *yx'z*, and the vertical rod *v'* is then supported by the uncut part. In order to make the second's hand point to 0″ on the dial plate when the wiper sets off the detent *i* fig. 187, let us suppose that the second's hand indicates 15″ on the dial plate when the detent sets out, or rather when the vertical rod which supports the end of the lever falls, we have only to turn the second's hand 15″ upon its axis in a direction opposite to that of the ratched wheel, and the object in view will be obtained.

Fig. 186.

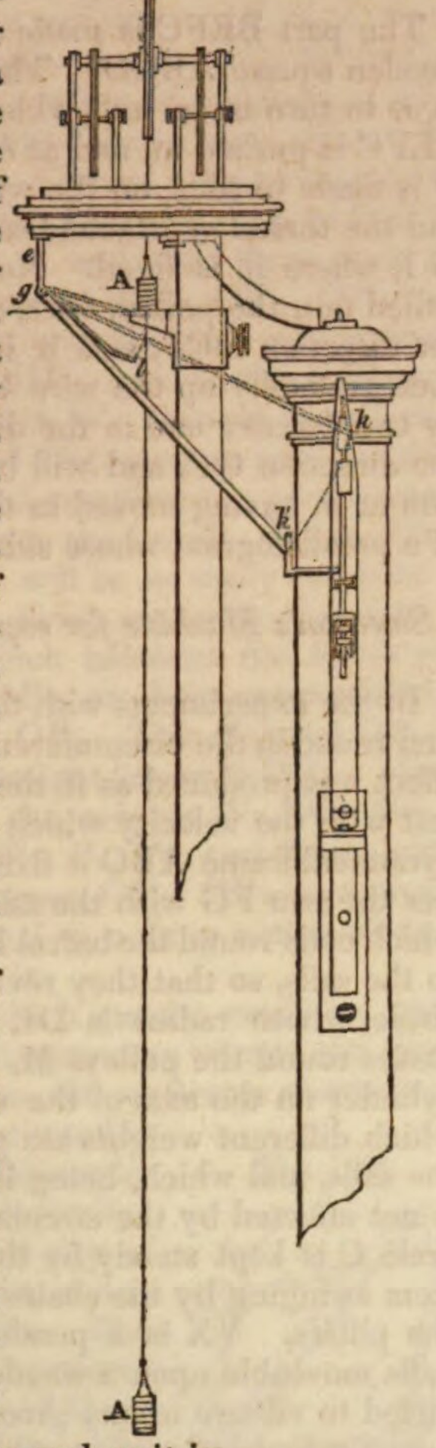
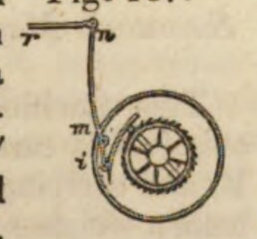


Fig. 187.



Dunn's improved Atwood's Machine.

Mr. Dunn of Edinburgh has introduced two very valuable improvements into this machine. The first consists in selecting a line for suspending the weights of as delicate a texture, and possessing as little rigidity as possible. He was led to this improvement in consequence of finding by experiment that the greater proportion of the whole resistance of a well made Atwood's Machine is to be ascribed to the rigidity of the cord employed; a circumstance which Mr. Atwood had entirely overlooked. The second improvement consists in supporting the axis of the large wheel or pully in the manner shewn in fig. 6, plate CCCXLIX, which represents the machine removed from the pillar on which it must be raised when used. The mode of supporting the axis will be more readily perceived in the annexed figure, where AB represents the axis terminating in finely finished conical points of tempered steel resting as represented on the sides of the conical agate caps C, D, care being taken to adapt the form of the points of the axis and the cups to each other, so that the portions of the axis in contact with the agates may be of the smallest possible size.

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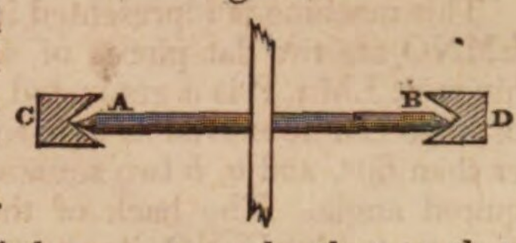
Fig. 188.



The agate caps are inserted into the ends of the large milled screws AB in the frame of the instrument, fig. 6, plate CCCXLIX. When the wheel is put into its place the screws A, B are turned forwards until they approach sufficiently near each other to prevent the wheel being thrown out of its place, but not so near as to force the points of the axis against the bottoms of the caps. In a number of experiments made by a committee of the Society of Arts for Scotland in 1828, appointed to investigate the merits of Mr. Dunn's machine, it was found that when the wheel weighed 4458 grains (including the cord) the strings being loaded with 60 grains each, the addition of $\frac{1}{10}$ of a grain produced a very sensible motion; and when the load of each string was increased to 2423 grains, $\frac{4}{10}$ of a grain were sufficient. Hence it would appear from these data, that under equal pressures the rigidity was three times the friction.

These results, however, when used for computing the momentum of the wheel gave an inertia much greater than what its form and weight would have sanctioned, and the experiments were repeated and a few others added. With these the results were still discordant, and it was at last found that they had been materially affected by the vibrations of the floor on which the machine stood. In order to overcome this difficulty another set of experiments was instituted for detecting the amount of resistance by observing its effects upon motions caused by different accelerating forces. In all these the space described was seven feet, and the time was measured by a metronome adjusted to $\frac{1}{2}$ seconds. When one of the ends was loaded with 40, and the other with 37 grains, the time was $26\frac{1}{4}$ seconds; and each end being loaded with 2423 grains, and an additional weight of 10 grains superadded to one, the time was 20 seconds, while when the accelerating force was 100 grains, it was only $5\frac{1}{2}$ seconds.

From these experiments the whole resistance was found to be $2\frac{1}{2}$ grains, ($\frac{1}{2}$ grains more than that given by Atwood for the resistance of his machine), and the inertia came out exactly to 2000 grains. It is probable, however, that of the 2 grains of friction allowed by Atwood, $1\frac{1}{2}$ was owing to the greater rigidity of his cord, and only $\frac{1}{2}$ grain to real friction. Such a near coincidence in the performance of the two machines, shews that for all practical purposes the simple machine of Mr. Dunn is as good as the more complex one originally invented by Mr. Atwood, and will, from its cheapness, be used in preference, except, perhaps, in the few cases where the machine is desired to be the best possible, and without any regard to the

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cost. But, even in this case, the greater liability to be affected by dust, may render the advantages of the original form doubtful. The object still to be aimed at is the reduction of the stiffness of the silk line, for till that is still further reduced the diminution of the friction, which is the smaller portion of the whole resistance, is less essential, and Mr. Dunn, in partly disregarding it, has effected an important practical improvement.

The theory of this machine is a particular one of D'Alembert's principle of the distribution of motion, viz. that in which the two inclined planes have a vertical position. See Poisson's *Traité de Mecanique*, p. 46.

Machine for illustrating the Theory of the Wedge.

Pl.cccxlix This machine is represented in fig. 7, where KILM and LMNO are two flat pieces of wood joined together by a hinge at LM; P is a graduated arch on which these pieces of wood can be moved so as to subtend any angle not greater than 60°, and *a*, *b* two screws for fixing them at the required angle. The back of the wedge will therefore be represented by IKNO, its sharp edge by LM, and its two sides by KILM, LMNO. The weight *p* suspended to the wedge by the hook T, and the weight of the wedge itself, may be considered as the force employed to drive the wedge. The wooden cylinders AB, CD, have their extremities made like two flat circular plates to prevent the wedge from slipping off at one side. To the pivots of these cylinders, two of which are represented at *e* and *f*, are fastened the cords *e*W, *f*U, CV, AX, which passing over the pulleys U, V, X, W are fastened to the two bars *u v*, *x w*, on which any equal weights Y, Z may be hung at pleasure. The tendency of these weights is evidently to draw the cylinders towards each other, and they may therefore be regarded as the resistance of the wood acting against the sides of the wedge. The cylinders themselves are suspended by their pivots to the threads E, F, G, H, which may be fixed to the ceiling of the room, or to the horizontal beam of a frame made on purpose. By placing various equal weights at Y and Z, it may be easy to determine the proportion between the power and the resistance when the wedge is in equilibrio. In this machine the impelling power is the pressure of the weight *p*, whereas, in the real wedge, the impelling power is always an impulsive force which is infinitely more powerful.

Machine for illustrating the effects of the centrifugal force in flattening the poles of the Earth.

Pl.cccxlix Fig. 8. represents this machine, which consists of two flexible circular hoops, AB and CD, crossing one another at right angles, and fixed to the vertical axis EF at its lower extremity, but left loose at the pole or intersection *e*. If this axis be made to revolve rapidly by means of the winch *m*, and the wheel and pinion *n*, *o*, the middle parts A, B, C, D will, by their centrifugal force, swell out and strike against the frame at F and G; if the pole *e*, when sinking, is not stopped by means of a pin E fixed in the vertical axis. The hoops, therefore, will have a spheroidal form; the equatoreal being longer than the polar diameter.

Machine for trying the Strength of Materials.

Machine for trying the strength of materials, Plate cccl. Fig. 1.

The piece of wood, whose strength is to be tried, is represented by EF, and the force is applied to it by means of the winch A. which winds up the rope BC, passing over the pulley *n*, and below the pulley *m*, and attached to the point D of the beam EF. The pulleys slide on two parallel bars fixed in a frame, held down by a projecting point, at G, of the lever GR, which is graduated like a steelyard, and measures the force employed. The beam EF is held by a double vice IK with four screws, two of which are invisible. When a wire is to be torn it is fixed to the cross bar LM; and when any body is to be crushed, it must be placed beneath the lever NO, the rope BC being fixed to the hook N, and the end O being held down by the click which acts on the double ratchet OP. The lever is double from O to Q, and acts on the body by a loop fixed to it by a pin. See *Young's Natural Philosophy*, vol. i. p. 768, from which this drawing and description are taken.

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Machine for shewing the Composition of Forces.

Machine for shewing the composition of forces. Plate cccl. Fig. 2.

The part BEFC is made to draw out or push in to the wooden square ABCD. The pulley H is joined to BEFC, so as to turn on an axis which will be at H when the square BEFC is pushed in, and at *h* when it is drawn out. A ball G is made to slide on the wire *k*, which is fixed to BEFC, and the thread *m* attached to the ball goes over the pulley to I, where it is fixed. Now, when the piece BEFC is pulled out, the pulley, wire, and ball move along with it, in the direction DCF, and it is evident that the ball G will slide gradually up the wire *k*. It is therefore acted upon by two forces; one in the direction GH, and the other in the direction GC, and will be found at the end of the motion at *g*, having moved in the direction G *g*, the diagonal of a parallelogram whose sides are GH, GC.

Smeaton's Machine for experiments on Windmill Sails.

Apparatus for wind mills. Plate cccl. Fig. 2.

In the experiments with this machine, the sails were carried round in the circumference of a circle, so that the same effect was produced as if the wind had struck the sails at rest with the velocity which was thus given them. In the pyramidal frame ABC is fixed to the axis DE, which carries the arm FG with the sails GI. By pulling the rope Z, which coils round the barrel H, a motion of rotation is given to the sails, so that they revolve in the circumference of a circle, whose radius is DI. At L is fixed a cord which passes round the pulleys M, N, O, and coils round a small cylinder on the axis of the sails, and raises the scale C, in which different weights are placed for trying the power of the sails, and which, being in the direction of the axis DE, is not affected by the circular motion of the arm DG. The scale C is kept steady by the pillars Q, R, and prevented from swinging by the chains S, T, which hang loosely round the pillars. VX is a pendulum composed of two leaden balls moveable upon a wooden rod, so that they can be adjusted to vibrate in any given time. The pendulum hangs upon a cylindrical wire, on which it vibrates as on a rolling axis.

Smeaton's Machine for experiments on Rotatory Motion.

Apparatus for rotatory motion. Plate cccl. Fig. 4.

This machine is exhibited in fig. 1, where the vertical axis NB is turned by the rope M passing over the pulley R, and carrying the scale S. The axis NB carries two equal leaden weights K, D, moveable at pleasure on the horizontal bar HI. The upper part N of the axis is one-half the diameter of the part M, so that when the rope is made to wind round N, it acts at half the distance from the axis, at which it acts when coiled round M. When the rope is wound round N, the same force will produce in the same time but half the velocity which is produced when the rope coils round M, the situation of the leaden weights being the same; but when the weights K, L, are removed to a double distance from the axis, a quadruple force will be required in order to produce an equal angular velocity in a given time.

Machine for Illustrating the Parallelogram of Forces.

This apparatus, described by Professor Moseley, is shewn

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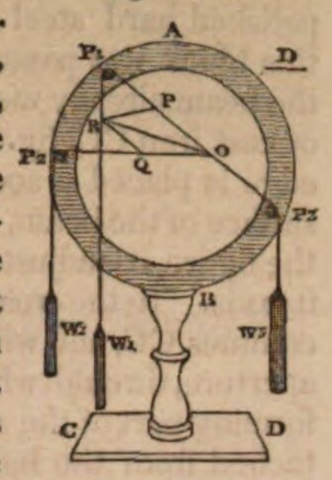
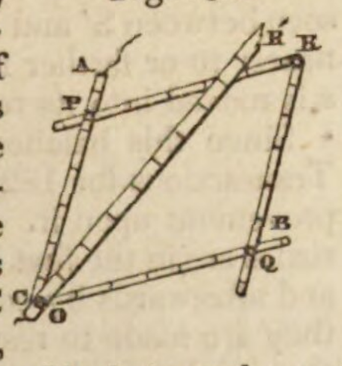
in the annexed figure 189, where AB is a circular frame or ring of wood supported vertically upon a stand BCD. Three moveable pulleys, P_1, P_2, P_3, made with as little friction as possible, are so constructed that they can be placed on any part of the circumference of the ring AB, the wheels being parallel to the surface of the ring. Three fine silken strings, united at one point O, are made to pass over the pulleys in the lines OP_1, P_2, P_3, and to support at their other extremities the weights W_1, W_2, W_3. After a certain time these weights will come into a position of equilibrium, when the three pieces acting at O will balance each other. Fill up the interior part of the ring AB with a board slightly depressed beneath the nearer surface of the ring, so that the strings may not rub against it, and draw lines upon the board in the direction of the strings OP_1, OP_2, OP_3; and taking the tenth of an inch, or any other unit of magnitude, divide the lines OP_1, OP_2, OP_3, into tenths. Then, if there are six units of weight in W_1, (ounces or any other unit), make OP=6-10ths, and OQ as many tenths as there are units or ounces in W_2, and complete the parallelogram OPRQ, by drawing lines upon the board. When this is done, we shall find that there will be as many *tenths* of an inch in the diagonal OR, as there are units of weight or ounces in the weight W_3, which balances the forces produced along the lines OP_1, OP_2, or their compounded or united action in the diagonal OR. This diagonal OR will be found to lie in the same straight line with OP_3. Hence it follows that whatever be the weights W_1, W_2, W_3, or the position of the pulleys P_1, P_2, P_3, two forces acting along the sides of a parallelogram OP_1, OP_2, and proportional to these sides, are equal to a force acting along its diagonal, and proportional to it.

Fig. 189.



In place of using strings which cannot easily be graduated, and therefore renders it necessary to note the graduations on a board behind them, the apparatus shewn in the annexed figure has been substituted in the class of Experimental Philosophy in King's College, London. A parallelogram OPQR is formed of thin slips of boxwood, so as to be very light, and is divided into inches and tenths. The slips are united at the angles by moveable joints, and the joints P and Q are made to slide along either of the sides which they unite. A slip of wood RC moves freely along with OP and OQ, on the joint O. An inch, or any part of it, being taken as the unit of length, and an ounce as that of weight, the joint P is made to slide along OP, until OP contains as many inches as there are ounces in the weight W_1; and Q is moved till OQ contains as many inches as W_2 contains ounces. By means of other sliding joints, PR and PQ are made equal to OQ and OP. Strings are then fastened to the ends A, B, C of the slips OP, OQ, and R′O, and these are passed over the pulleys P_1, P_2, P_3 of the wooden ring in the preceding instrument, and made to suspend the weights W_1, W_2, W_3. In a certain time, as before, the system of forces will come into a state of equilibrium; and when this has taken place, it will be found that the slip OR′ has taken the position of the diagonal OR, and that it contains as many *inches* as there are *ounces* in W_3. This instrument was made by Messrs. Watkins and Hill, philosophical instrument makers, Charing Cross.

Fig. 190.

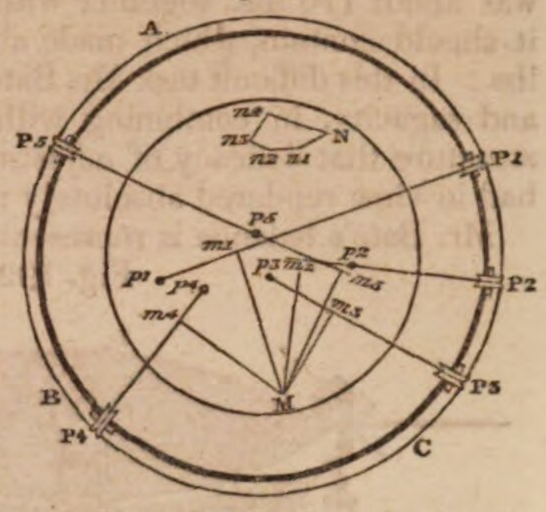


Apparatus for Illustrating the Equilibrium of a number of Forces.

Description of Machines.

Professor Moseley,[1] in his excellent work on mechanics, has described an instructive apparatus for exhibiting the equilibrium of a number of forces applied to different points of a body, but acting all in one place. This apparatus is shewn in the annexed figure, where ABC is a smooth flat board, resting on three small ivory balls, laid on a smooth horizontal table, and round the edge of the table are fixed a number of pulleys, P_1, P_2, P_3, the plane of their action being perpendicular to that of the table, and each having the highest point of its circumference or groove level with the surface of the board ABC. Assume any points on the board, viz., p_1, p_2, p_3, p_4, and having fixed strings at them, make these strings pass over the pulleys P_1, P_2, P_3, P_4, &c., and suspend weights at the other ends, represented by the letters P_1, P_2, P_3, &c. If this system of forces is left to take up a position of equilibrium, the following relation will be found between the directions of the forces and their measures P_1, P_2, P_3, &c. If from any point M on the surface of the board ABC, we draw perpendiculars Mm_1, Mm_2, Mm_3, &c., upon the directions p_1, p_2, p_3, &c., of the forces P_1, P_2, P_3, &c., we shall find that the sum of the products arising from multiplying the lengths of the perpendiculars Mm_1, Mm_2, &c., by the forces P_1, P_2, &c., in whose direction they are drawn, taken in reference to those forces which tend to turn the system about that point, will be equal to the sum of these, taken in reference to the forces tending to turn it in the opposite direction. In the present figure, for example, we shall find $\overline{P_1 \times Mm_1} + \overline{P_2 \times Mm_2} + \overline{P_3 \times Mm_3} = \overline{P_4 \times Mm_4} + \overline{P_5 \times Mm_5}$.

Fig. 191.



Another property of such forces is deducible from this apparatus. If the forces P_1, P_2, &c., are all made to act upon a single point, but parallel to their present directions, they will all be in equilibrio, and the point remain at rest.

When a system of forces P_1, P_2, P_3, and P_4, is not in equilibrium, we may determine the magnitude and direction of a fifth force P_5, which shall place them in equilibrium. On the surface of the board take any point N, and draw Nn parallel to $P_1 p_1$, so as to represent the force P_1; and in like manner $n_1 n_2$, $n_2 n_3$, $n_3 n_4$, representing the other three forces P_2, P_3, and P_4; then, if we join N and n_4, the line Nn_4 will represent in magnitude, and be parallel in direction to P_5, the force required to balance the other force.

We must now find where to apply this balancing force, in order to satisfy the condition expressed in the preceding formula. This will be effected by applying it parallel to Nn, and at such a distance from M, that the product of $\overline{P_5 \times Mm_5}$ may be equal to the sum of the similar products of all the other forces. The distance Mm_5 may be easily found, by dividing the difference of the sum of the products about M by the force P_5. If we now draw through M a line Mm_5, equal to the distance found above, and perpendicular to Nn_4, then a line $P_5 p_5$, drawn perpendicular to this, is that in which the force must be applied. The force P_5, now found, is the *resultant* of all the other forces; for

[1] *Treatise on Mechanics applied to the Arts*, p. 20.

Description of Machines.

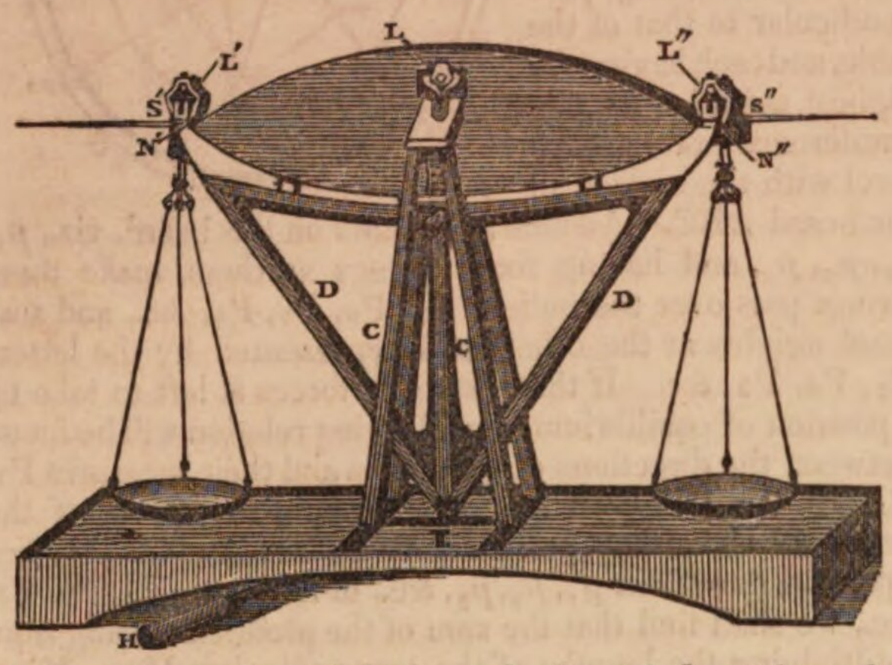
if all the rest were removed, and this put in their place, the equilibrium would continue.

Description of Mr. Bate's Balance for verifying the National Standard Bushel.

When Captain Kater and Mr. Bate were employed by government in the adjustment and construction of the new standard weights and measures, they were under the necessity of constructing a balance capable of determining a weight equal to that of the standard bushel measure, which was about 170 lbs., together with the eighty lbs. of water it should contain, which made altogether a weight of 250 lbs. In this difficult task Mr. Bate has exhibited great skill and sagacity, in combining with strength and solidity of structure that delicacy of adjustment which the object he had in view rendered absolutely necessary.

Mr. Bate's balance is represented in the annexed figure.

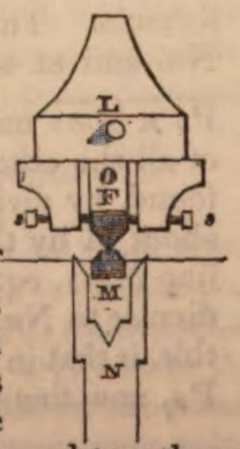
Fig. 192.



In the construction of the beam he first tried cast iron; but though it was as light as was consistent with the required degree of strength, the inertia of the mass was so considerable, that much time would have been lost before the balance would have answered to the small differences he wished to ascertain. Lightness being essentially necessary to the sensibility of the balance, and bulk being also very desirable, in order to preclude such errors as might arise from partial alterations of temperature in the beam, he determined to employ dry mahogany. The beam was therefore made of a plank of this wood, about seventy inches long, twenty-two inches wide, and $2\frac{1}{4}$ thick, tapering from the middle to the extremities. An opening was cut in the centre of gravity of the beam, as at L, and strong blocks screwed to each side of the plank, to form a bearing for the back of a knife edge which passed through the centre. Similar blocks were likewise screwed to each side of the plank at its extremities, to form a bearing for the knife edges which support the scales or pans.

In order that the whole weight should not be thrown upon short portions of the knife edges, as was usually the case, by which these edges were exposed to injury, as well as to a change of form, Mr. Bate made his knife edges long, the central one being six inches, and the other two five inches in length. They were triangular prisms, with equal sides, each being 3-4ths of an inch long, very carefully finished. The angles were of course 60° each, but they were ultimately wrought to an angle of 120°, which prevented all risk of injury, without impeding the rotation of the beam.

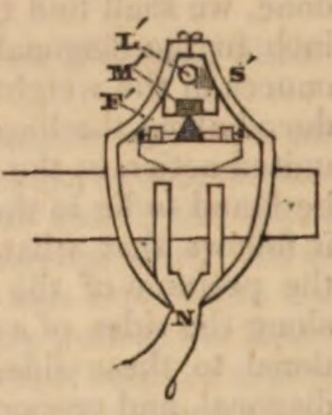
Fig. 193.



The central knife edge, and the mode of attaching it, and the plane which supports it to the beam L, and to the frame N, are shewn in the annexed figure. The knife edge F is screwed to a thick plate of brass L, the touching surfaces having been previously ground together. The support M upon which the knife edge rested, and revolved through its whole length, was formed of a plate of polished hard steel screwed to a block of cast iron; and this block was passed through the opening in the centre of the beam already mentioned, and properly fixed to the frame of cast iron CC, fig. 192. By means of screws *s*, *s*, the knife edge is placed as accurately as possible at right angles to the surface of the beam, and by means of other screws, not seen in the figure, it is adjusted so as to be slightly above the centre of its axis. In the cross horizontal bar, which is sustained by the columns CC, and which carries the steel plane M, there is an aperture, through which a fork-shaped piece of brass N passes, forming part of the stand DED. This fork is completely detached from the beam when the balance is in use; and by the motion of the handle H, it can be raised so as to make the fork catch a piece L (see fig. 193), projecting from the piece of brass which carries the knife edge. Two similar hooks are placed at the ends of the frame DED, by which the other two knife edges may be raised above their supporting planes by the motion of the handle H; and by this means the three knife edges are protected from that injury which they would receive from always resting upon the steel planes.

The mechanism of the ends of the beam for carrying the knife edges and their steel planes, is shewn in the annexed figure. These pieces project from the ends of the beam, and are placed at exactly equal distances from the fulcrum, or central knife-edge. In these pieces the knife edge F has its edge turned upwards. The scales or pans are each attached by a hook to the lower end of stirrups, shewn at S′, which receive between their two uppermost branches the extremity F′ of the beam. The steel plane M′ is fixed to the upper branches of the stirrup, and rests upon the knife edge when the balance is in use. The knife edges are adjusted, like the central one, by small screws, which give it a horizontal and a vertical motion. The adjustment of the central knife edge to a point a little above the centre of gravity of the beam, is facilitated by means of small weights which screw on the wires seen between S′ and N′, in fig. 192; and by screwing these nearer to or farther from the fulcrum, the centre of gravity *s* is moved into its required place.

Fig. 194.



Since this balance was described in the Philosophical Transactions for 1826, Mr. Bate has made a very great improvement upon it. By an ingenious device, the beam and scales are in the first instance suspended on cylindrical axes, and afterwards by continuing the motion of the handle H, they are made to rest upon the knife edges. In this way the weights in the opposite scales may be nearly balanced, while the beam and scales rest upon the cylindrical axis, and the extremely delicate part of the operation will then be completed in a shorter time when the beam and scales are put upon the knife edges.

The performance of this balance was fully equal to the expectations of Captain Kater and Mr. Bate. With 250 lbs. in each scale, the addition of a *single grain* produced an immediate variation in the index of *one twentieth of an inch*, to a radius of fifty inches. Hence the balance was sensible to the $\frac{1}{175000}$ part of the weight.[1]

Description of Dr. Black's simple and delicate Balance.

This simple and accurate instrument which any person may readily construct for himself, was invented by the celebrated Dr. Black, and an account of it communicated to James Smithson, Esq. The beam AB was a thin piece of fir wood not thicker than a shilling, a foot long, $1\frac{1}{2}$-10ths of an inch thick at each end, and twice that thickness at

[1] See *Phil. Trans.* 1826, Part I. p. 11. and Moseley's *Treatise on Mechanics*, p. 70.

Description of Machines.

the middle. The whole length was divided into twenty parts by transverse lines, and each of these subdivided into halves and quarters. One of the smallest needles *mn* was fixed across the middle with wax for the horizontal axis. A piece of plate brass, CD is bent so as to form three sides of a cube. It rests on its middle side, and the two vertical sides form the fulcrum on which the needle *mn* rests. The height of *mn* above the table is only $1\frac{1}{2}$ or two-tenths of an inch, so as to allow only a very limited play to the beam AB. The edges upon which the needle rests are ground at the same time on a plain surface. The weights were one globule of gold weighing one grain, and two or three others one-tenth of a grain each, along with a number of small rings of fine brass wire formed by coiling it round a thicker brass wire into a close spiral. The end of the wire being tied hard with a waxed thread, the coiled wire was put into a vice, and a sharp knife being applied and struck with a hammer, a great number of the coils were cut at one stroke, and were found to be as equal to one another as could be wished. These weights were about the 1-30th of a grain each, and by means of them the weight of any body from one grain to the $\frac{1}{1200}$ of a grain could be readily weighed. By using a thinner beam and grinding the needle to an edge, a still more delicate balance could be made, and a paper scale added if necessary.[1] Captain Kater has found that a balance of this kind is sensible to the $\frac{1}{1000}$ part of a grain when loaded with ten grains. He found it necessary, however, when accuracy was essential, to use a scale of thin card paper of the form shewn in the annexed figure, a thread being passed through the two ends in order to bring them together.[2]

Fig. 195.

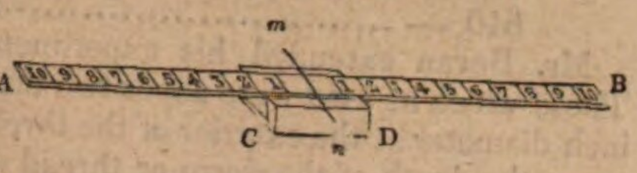
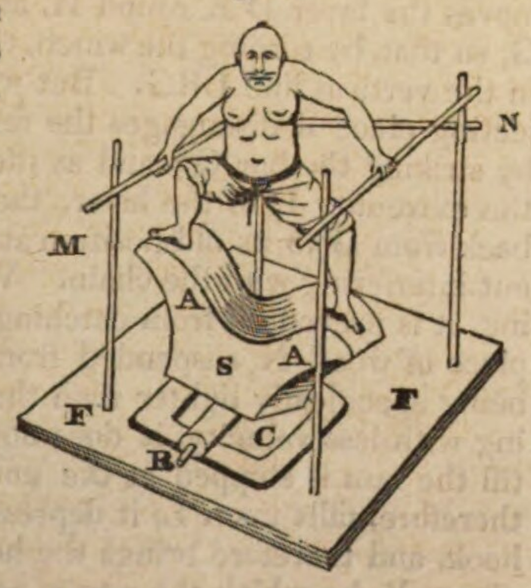


Fig. 185.

Description of a Chinese Mangle.

This simple and ingenious piece of machinery is represented in fig. 197. which the writer of this article found on a large scale on a series of paper-hangings for rooms. The late Andw. Waddel, Esq. of Hermitage Hill, who had seen it at work at Canton in 1786, had previously furnished us with a drawing of it. On the floor FF, which is paved with tiles, was a concavity C lined with hard wood. A roller R, having the cloth to be mangled wrapped round it, was placed in this concavity. The weight used was a sandstone S of about 11 cwt., and shaped as at A, so as to leave the line of direction from its centre of gravity, falling within either of its two bases. By resting on the timber frame MN, the workman steps on the uppermost end of the stone S, and causes its under surface to descend gently upon the rolled up cloth R. He is then in the position shewn in the figure, and by the alternate pressure of each foot he gives the stone an oscillating motion which moves the roller over the cloth and the whole of the smooth concave surface C, and with any degree of velocity that he chooses, till the mangling of the cloth be completed.

Fig. 197.



Account of the Mechanical Process of cutting Steel with Soft Iron.

As this process seems to depend on a new principle of mechanical action, it may probably be modified and extended, so as to produce effects which have not hitherto been contemplated. The process to which we allude seems to have been invented by the *Shakers* in America. It consists in cutting the hardest steel by means of a *buzz*, or wheel of soft iron, made to revolve with great rapidity. By this means a file may be cut in two, while the soft iron plate is not in the least degree impressed by the file. Mr. Barnes cut a saw plate and formed the teeth by the same means. In the process a band of intense fire appeared round the soft iron wheel, which emitted sparks with great and continued violence. Professor Silliman was of opinion that this was nothing more than "a peculiar method of cutting *red hot*, or possibly *white hot* steel; for the mechanical force produces these degrees of heat, and the steel loses its temper at the place of action." (Silliman's *Journal*, vol. viii. p. 342. But it appears from a very careful examination of the process by MM. Darien, and Colladon of Geneva, that the process has a more recondite origin. The following is a general abstract of the results which they obtained:

1. Having found that the iron wheel was covered with small fragments of the steel, they could see by a microscope no appearance of softening; on the contrary, they found these fragments as hard as the best tempered steel.

2. Having fitted up a lathe by which they could give a determinate velocity to the iron wheel, they found that with a velocity of 34 feet per second, an iron wheel was easily cut by a steel graver without any reaction on the graver. With a velocity of 34 feet 9 inches the iron was less attacked, and the graver began to experience the impression from the iron. At a velocity of 35 feet 1 inch, the action of the iron on the graver was decided, and increased with greater velocities, till at a velocity of 76 feet per second, the iron was no longer touched by the steel, while the steel was cut with the greatest violence.

3. In order to determine the effect of softening or annealing on the steel, our authors examined the fragments of steel detached from the graver at different velocities, from 40 to 100 feet per second; and in every case when the iron was only touched for an instant with the steel graver, the latter exhibited no trace of annealing; but when the graver was long and strongly pressed it sometimes became red hot. In that case, however, the fracture of the steel became quite different, and *the action upon it was rather diminished than increased.*

4. Having thus ascertained that the effect is not owing to the annealing of the steel, and found that the effect was not increased by the fragments of steel, which after some time collect on the iron wheel, our authors justly suppose that the whole effect is directly mechanical, arising from the brittleness of the steel, which is torn asunder before it has time to introduce itself amongst the molecules of the soft iron; and they consider it as analogous to the penetration of wood by a ball of tallow.

5. Upon using wheels made of a mixture of copper and iron, and wheels of pure copper, no effect was produced by them on the graver, though they cut different alloys harder than themselves.

In these experiments, however, a very remarkable effect occurred. *Little or no heat was generated, when files and steel springs were held firmly against the revolving copper wheel;* and our authors observed several other curious facts, which they mean to study with greater care, connected with the production of heat by the friction of metals. See *Edinburgh Journal of Science*, vol. i p. 341.; *Bibliotheque Universells*, April 1824, p. 283—290, and Silliman's *Journal*, vol. vi. p. 336—354.

[1] *Annals of Philosophy*, N. S. vol. x. p. 52.

[2] Lardner's *Mechanics*, p. 293.

Description of Machines.

On the adhesion of solid bodies as displayed in the Lifting Plug, and in the power of Nails.

The simple instrument called a Lewis for lifting loose stones has been long known and employed in architecture. A much more simple and efficacious contrivance was nearly forty years ago invented by Mr. Richardson of Keswick, and called the lifting plug. It excited little notice till it was made known in Scotland by Mr. Spottiswoode of Spottiswoode, who used it to a greater extent than any other person, and found it an invaluable apparatus for pulling large stones out of the soil.

A cylindrical hole about two inches deep is cut vertically out of the stone by the steel boring chisel used by masons. A cylindrical plug of common iron, a little less than that of the hole, is then driven into it, about an inch deep, by two or three smart blows of a hammer. By using a common windlass or pulley attached by a hook carried by the plug, the heaviest stones may be raised, and the largest masses of stone torn out of the ground by no other fastening than the adhesion of the plug to the hole. When the stone is raised to its place, the pulley may be detached from it by giving a sharp stroke or two from a hammer upon the stone. The elasticity of the stone is no doubt the cause of the adhesion of the plug, the stone grasping the plug as wood does a polished nail; but another cause undoubtedly is the enormous friction occasioned by the particles of the stone being jammed into the surface of the soft iron plug. It has been thought by some that the first of these causes is the only one, and that the circumstance of the plug being detached by a slight vibratory motion of the stone is a proof of this; but if the two causes which we have mentioned, concur in producing the adhesion of the plug, then it is obvious that when one of these causes of adhesion is removed by the vibrations of the stone, the other being inadequate to sustain the weight, the stone must quit its hold of the plug. Independently of this argument, however, it appears to us that the same cause which releases the plug from the influence of elasticity, tends also to relieve it from the abraded material which unites the surface of the stone with the surface of the iron. In all vibratory movements there is an alternate contraction and extension of the vibrating body, and in one of these phases no doubt the great weight of the stone overcame the diminished force by which it was previously sustained. A drawing and description of the machine for raising stones, by Professor Low, will be found in the *Edin. Phil. Journal*, first series, vol. iv. p. 281.

Bevan's experiments on the adhesion of nails.

The subject of the adhesion of nails in wood is so intimately connected with the principles of the lifting plug, that our readers will, we are sure, thank us for any information on the subject. The only person who has directly investigated the subject is Mr. B. Bevan,[1] who constructed a machine for measuring the force with which nails adhere to wood into which they are driven. He employed it in drawing out nails of different lengths, from a quarter of an inch to $2\frac{1}{2}$ inches long, from dry Christiania deal, at right angles to the grain of the wood. The following table contains the results of his experiments:—

Kind of Nail.	No. of Nails to the Pound.	Inches in Length.	Inches driven into the wood.	Pounds required to extract them.
Fine sprigs,	4560	0·44	0·40	22
Do.	3200	0·53	0·44	37
Threepenny brads,	618	1·28	0·50	58
Cast iron nails,	380	1·00	0·50	72
Sixpenny nails,	73	2·50	1·00	187
Do.	—	—	1·50	327
Do.	—	—	2·00	530
Fivepenny,	139	2·00	1·50	320

The weights necessary to press a sixpenny nail into dry Christiania deal, to different depths, are as follows:— Description of Machines.

Pressure required.	Depth in the wood.
24 lbs.	0·25 inches.
76 —	0·50 —
235 —	1·00 —
400 —	1·50 —
610 —	2·00 —

Mr. Bevan extended his experiments to screw nails. Those which he used were about two inches long, $\frac{20}{100}$ of an inch diameter at the exterior of the threads, $\frac{15}{100}$ at the bottom; the depth of the worm or thread was $\frac{55}{1000}$ of an inch and the number of threads in an inch twelve. They were screwed through pieces of wood exactly half an inch thick, and drawn out by the weights stated in the following table:—

Dry Sycamore,	830 lbs.
Dry sound Ash,	790 —
Dry Beech,	790 —
Dry Mahogany,	770 —
Dry Oak,	760 —
Dry Elm,	635 —
Dry Beech (another kind),	460 —

When the wood was deal, or any of the softer woods, the force required to draw out the nails was only about one-half of the above weights. The mean of the first six experiments is 762 lbs., and of all the experiments, 719. Hence we may infer that the force required in the softer woods is about 370 lbs.[2]

Bunce's Pile Engine.

A side view of this engine is shewn in figs. 5 and 6. It consists of two endless ropes or chains A, connected by cross pieces of iron B, B, &c. (fig. 6.) which pass round the wheel C, the cross pieces falling into corresponding cross grooves, cut in the periphery of the wheel. When the man at S, therefore, drives the wheel *m* by means of the pinion *p*, he moves also the wheel C fixed on the axis of *m*, and makes the double ropes revolve upon the wheels C, D. The wheel D is fixed at the end of a lever DHK, whose centre of motion is H, a fixed point in the beam FT. Now, when the ram L (fig. 5, 6,) is fixed to one of the cross pieces B by the hook M, the weight of the ram, acting by the rope, moves the lever D K round H, and brings the wheel D to G, so that, by turning the winch, the ram L (fig. 5.) is raised in the vertical line LRG. But when it reaches R, the projecting piece R disengages the ram from the cross piece B, by striking the bar Q; and as the weight is removed from the extremity D of the lever, the counterpoise I brings it back from G to its old position at F, and the ram falls without interfering with the chain. When the hook is descending, it is prevented from catching the rope by means of the piece of wood N suspended from the hook M at O; for being specifically lighter than the iron weight L, and moving with less velocity, it does not come in contact with L till the ram is stopped at the end of its path. When N, therefore, falls upon L, it depresses the extremity M of the hook, and therefore brings the hook over one of the cross pieces B, by which the ram is again raised. Plate CCCL.

Fixed Iron Crane.

Plate CCCLI. figs. 4 to 7, shew the elevation, plan, section, and outer frame of a fixed iron crane or compound winch, used for raising heavy weights to a considerable height, as it is employed at the present day for the erection of buildings, &c. The triangular framings FFF, &c., are of cast iron, and give support to three horizontal revolving shafts of malleable iron running in cylindrical journals. The princi-

[1] See *Phil. Mag.* vol. lxiiii. p. 168. and *Edin. Journal of Science*, vol. i. p. 150.
[2] *Phil. Mag.* Oct. 1827, p. 291. and *Edin. Journal of Science*, No. xv. p. 159.

Mechain. pal shaft is in the axis AX of the hollow cast iron barrel BB, to which one end of the rope is attached, so as to be coiled and uncoiled by the revolutions of the barrel, in opposite directions. The barrel carries with it a toothed wheel WW, connected with a pinion V placed on a secondary axis QM in such a manner as to revolve freely upon it, or be carried round along with it at pleasure. On the end of this axis QM are placed the crank handles, to which the power may be applied through the pinion V to the wheel W and the barrel B directly. But if a more powerful and slower motion be required, the means of obtaining it are provided in connection with a third axis PN; this axis is immediately connected with the wheel W by the pinion V, which revolves with it, and turns the axle PN, and with it the secondary wheel VV. But the circumference of VV is acted on by the teeth of the pinion TT, which is also made to revolve independently of its own axle, or in connection with it, by means of the lever LL and the clutches CC. The change of power is effected in the following manner: The drawings represent the pinions Y and T both disengaged from their axle, and revolving freely around it in oiled bushes; but if the smaller power is to be used, the attendant lays hold of the lever handle L, and drawing it towards T, engages the clutch towards Y with the pinion Y, and as the clutches C and C are feathered on the axle, they must revolve with it, and carry round that pinion with which they are engaged. In this way, the pinion Y being made to give the motion of the crank handles directly to the barrel, give the less power; but if the greater power and slower motion are to be used, the clutch at Y is disengaged, the lever is reversed, the pinion T is caught and carried round by the other clutch, and thus the motion of the axis QM is transferred through the wheel VV to the axis PN, and to the pinion V, which works on the primary wheel WW, and the power is increased in the ratio of V to T. When the lever L is placed, as in the figures, so that neither pinion is in gear with its axle, the barrel is free to revolve in the direction of any force applied to it, so that the weight may be run down with great rapidity; and the following contrivance gives a regulating power to this motion: An iron strap SSS embraces closely a wooden drum on the axis of BB, and is attached at both ends to bolts on either side of the fulcrum of the bar HI, which has a handle at H, at a considerable distance from the fulcrum, so that by depressing H, the drum may be firmly embraced by the friction strap SSS, and stopped at any point in its descent, or moderated to the requisite degree. This last appendage is of great consequence in saving time, and preventing the danger attendant on lowering the weights with great velocity. Mechain.

Revolving Jib Crane.

Plate CCCLII. figs. 1, 2, and 3, shew the plan, side elevation and back elevation of the revolving jib-crane or wharf-crane. Its wheels give a variable power in the same way as those in figs. 4, 5, 6, and 7, plate 351.

Fig. 4, is a detached portable equilibrium crane; its pyramidal iron base merely rests on the ground, and may even run on a road or railway, and when very great weights are raised, counterpoises may be placed on the platform with the attendants.

For the description of a great variety of useful machines, the reader is referred to the second volume of Gregory's Mechanics, and to Dr. Young's Natural Philosophy. See also HYDRODYNAMICS.

MECHAIN, PETER FRANCIS ANDREW, a well-known practical astronomer and geographer, was born at Laon, on the 16th April 1744. His father was an architect, and educated him with the intention of making him his successor in his business. He afterwards took charge of two young men at Sens, as their private tutor, and accidentally became acquainted with Lalande, under whose patronage he was subsequently brought forward as an observer, surveyor, and computer. He made two voyages with M. de la Bretonniére, and assisted him in surveying some parts of the coast of France. He was afterwards employed in various computations by the Marquis de Chabert, and the Duc D'Ayen. Having obtained a prize from the Academy of Sciences in 1782, for a *Memoir on Comets*, he became a member of the Academy the same year. About the year 1785, he undertook the publication of the *Connaissance des Tems*, and continued it till he was employed in geodetical operations at a distance from Paris. He was appointed member of a committee, along with Cassini, de Thury, and Legendre, to meet the English astronomers for the determination of the relative situation of the observatories, which had been proposed by Cassini. It was in these operations that he first brought Borda's circle into general use. In 1791 he was appointed, in conjunction with Delambre, to execute the intentions of the Constituent Assembly, with regard to the determination of a basis of linear measures. A variety of delays and difficulties occurred in these operations. In Spain he was wounded in the head and side, by an accident which occurred whilst he was inspecting a water-wheel; and the political circumstances of the times produced many embarrassments, which caused him to linger in Italy perhaps a little longer than was actually necessary; but the establishment of the *Bureau des Longitudes*, and his nomination as a member of it, determined his immediate return to Paris. He was now director of the Observatory, and he entered with great zeal on a series of observations, which were to rival those of Flamsteed, of Bradley, and of Maskelyne; but he seems to have been a little tired of the confinement, and he readily accepted, or rather solicited, the appointment to assist in the measurements required for the still farther extension of the arc of the meridian to the south of Barcelona. But the secret motive for his seeking this humbler employment appears to have been a desire to remove some doubts which he entertained respecting the latitude of Barcelona, as it appeared after his death from his papers, that there had been a discordance of 3″ in some observations which he had not made public. In this unfortunate undertaking, he paid a heavy penalty for any want of candour which may have been attributed to the concealment. Shipwreck and disease awaited him; and he died at last, on the 20th of September 1805, of a fever, which fatigue and a bad climate had brought on. From the time of his accident in Spain he had become habitually melancholy and timid, though regardless of personal danger in the pursuit of his professional objects. His whole time was occupied in observing and calculating; he published little; and never ventured to advance any reflections on the subjects which employed him, being probably more in the habit of acting than of speculating. He married, in 1777, Mademoiselle Thérèse Marjon, with whom he had become acquainted at Versailles. This connexion was in every respect happy; he was indebted to it for a competent fortune, and he left a daughter and two sons.

1. Of his publications the most important are to be found in the *Mémoires des Savans étrangers;* that is, besides some *Observations of eclipses and occulations*, a *Memoir on the comets of* 1532 *and* 1661, showing that they are not the same; and their non-appearance seven or eight years afterwards fully justified his conclusions, and the adjudication of the prize. 2. In the *Memoirs of the Academy*, from 1782 to 1784, there are several of his *Observations of transits, eclipses, occulations, and comets.* 3. There are also some letters of Méchain in Zach's *Geographical Ephemerides* about 1800, on the instruments of the *Parisian Observatory*, and on other subjects. 4. He edited the *Connaissance des Tems*, from 1786

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to 1794. (See LALANDE.) 5. *Base du système mètrique*, décimal. 3 v. 4. Paris, 1806, 1807, 1810. This last is the joint work of Méchain and his friend and colleague Delambre.

MECHANICS' INSTITUTIONS have for their object the instruction of the working classes in those branches of science and art, which are of practical application in the exercise of their several occupations.

It has been a subject of very considerable controversy to whom the honour of having originated those institutions ought to be attributed. Some have contended that to Professor Anderson, the founder of the institution in Glasgow, which bears his name, it is alone due; because in addition to the clauses in his will, which especially provide for the formation of a class of *manufacturers* and *artificers*, he had for a period of thirty years, whilst professor of natural philosophy in the university of that city, opened a class to which manufacturers and others had access, for the purpose of becoming acquainted with the fundamental principles of experimental physics. Others, again, have affirmed that although Professor Anderson had such an intention in view when he framed his will, it was only through the exertions of Dr. Birckbeck, the second professor of the Andersonian Institution, that the project was carried into complete and practical effect. Without going into the merits of this question, however, it appears to us that to Professor Anderson is certainly due the merit of having originated the *idea* of instructing that previously neglected but valuable portion of the community. But whilst we give all the weight to which that admission is entitled, we are of opinion that in as far as regards the usefulness of the idea when carried into effect, the merit is due to Dr. Birckbeck. Professor Anderson[1] was in the frequent habit of visiting and spending several hours in the workshops of the mechanics of Glasgow, and freely entering into conversation with them; amongst others he was often found at the workshop of our illustrious countryman James Watt, then a watchmaker in Glasgow; and it was in consequence of the avidity with which the workmen availed themselves of the theoretical information which on these visits he was in the constant practice of imparting, that he first conceived the idea of bringing within their reach those principles of science, the attainment of which had hitherto been confined to the higher and wealthier classes.

He then commenced within the walls of the university a course of lectures on natural philosophy, for the especial benefit of that class of society, and divided the course into two branches; one meeting four times a-week, in which the mathematical principles of the science were considered apart from experimental illustration; and the other, which met twice a-week, consisting entirely of those branches which admitted of such illustration, and in which the principles of mathematics were less called into operation. This latter class was regularly and numerously attended by a great many manufacturers and others engaged in operative occupations, and was continued for several years with great success; and he called it his *antitoga* class, in contradistinction to his regular academic attendance, which was denominated the *toga* class. It was in consequence of the decided improvement in the arts and manufactures of Glasgow, which from that time became very evident, and which Professor Anderson justly attributed to his instructions, that he conceived the truly philanthropic intention of bequeathing his ample fortune for "the good of mankind and the improvement of science." In the provisions of his will there was an especial reference to the formation of classes upon the principle of that which he had himself so successfully taught within the walls of the university.

Professor Anderson died on the 16th of January 1796; and at a meeting of his executors, held on the 23d of March following, it was resolved to carry his intentions into immediate effect. Accordingly on the 21st of September of the same year, Dr. Thomas Garnett was elected first professor of natural philosophy.

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The lectures however were at first only popular. Dr. Garnett, in 1800, was appointed to the chair of natural philosophy in the Royal Institution of Great Britain, founded at the suggestion of Count Rumford and Sir Joseph Banks; and Dr. George Birckbeck was elected in his stead. It was then, *upon the suggestion of Dr. Birckbeck*, that the trustees were enabled to give full effect to Professor Anderson's favourite idea, as expressed in his will, of affording instruction in experimental philosophy to the artizans of Glasgow. Such was the origin of the first mechanics' class, which has now been taught for upwards of thirty-six years with increasing success and advantage to this interesting class of students.

But important as was this era in the history of the class which was thus instituted, it was not until upwards of twenty years afterwards that the example was followed by any other city in the kingdom. At length, however, in 1821, the School of Arts for the instruction of mechanics was formed in Edinburgh; and within a year or two afterwards, the example was followed, and another institution of the same nature was originated in Glasgow, in consequence of some differences which had arisen between Dr. Ure, (Dr. Birckbeck's successor in the Andersonian Institution), and the students who attended his operative class. A great many of these left the Andersonian and founded the Mechanics' Institution, of which Dr. Birckbeck, at their solicitation, consented to become the patron. About the same time the London Mechanics' Institution was instituted, and within a very few years after this period there was hardly a city of any note in the kingdom which had not institutions of a kindred description.

As might have been expected, there exists a variety of opinions both as to the precise kind of instruction which these institutions ought to afford in order to carry their objects into the most complete effect, and also in regard to the manner in which they ought to be governed. Some conceive that the course of instruction ought to be of a popular nature, admitting amongst the lectures upon the graver and more abstruse sciences, prelections of a lighter and more attractive kind; whilst others are of opinion that the course ought to be strictly confined to those branches of physical science alone which are of practical application in the arts or manufactures. The management of several, indeed of the greater number, is entirely in the hands of the mechanics themselves; some have an admixture of these with the upper classes of society, whilst in others of a third description, the government is entirely vested in the latter, or wealthier classes.

Favourable as we are to the universal diffusion of knowledge amongst the great mass of the people, we conceive, that the paramount object which these institutions have in view, namely, the advancement of the arts and manufactures, will be most decidedly and advantageously promoted, by confining the attention of the student to those branches of the physical sciences which bear more especially on the great majority of the useful arts. We have seen and examined carefully the plans of study as followed by most of the leading institutions of this kind throughout the kingdom; but, whilst we generally approve of them all, we shall confine ourselves to a more extended outline of the course followed by the Edinburgh School of Arts, as being that which seems to us most likely to promote the great objects they all have in view. It being self-evident that the elements of mathematics, mechanical philosophy, and chemistry, are of the most general application to the useful arts, it has been the

[1] Professor John Anderson was the eldest son of the Rev. James Anderson, minister of the parish of Roseneath, in Dumbartonshire, and was born there in 1726.

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principal aim of the directors of that institution to urge the necessity of acquiring a knowledge of these upon the notice of the student by every possible means; and especially that they should thoroughly understand the fundamental principles of mathematics, both from the intimate connexion these have with all the physical sciences, and as supplying a course of mental discipline, highly favourable to the successful prosecution, at any after period of life, of those studies the principles of which are more immediately involved in the ordinary occupations of life, and by the application of which alone any decided improvements in the arts may reasonably be looked for. And in order to encourage the student to adhere steadily to a certain course of study, an honorary certificate or diploma was instituted, conferring on the successful candidate the privilege of availing himself gratuitously, during his life, of all advantages of the institution. That course of study is as follows:—

I. A junior class of mathematics meeting twice a-week, in which the following branches are taught: Arithmetic, including vulgar and decimal fractions; Algebra, as far as simple and quadratic equations; Geometry, first and second books of Euclid. In this class, a portion of each hour of teaching is devoted to exercises and examinations.

II. A senior class of mathematics meeting once a-week, in which the following branches are taught: Geometry, the remaining books of Euclid; Logarithms; Mensuration and Trigonometry, with their various practical applications. In this class, also, a portion of each hour of teaching is devoted to exercises and examinations.

III. A class of Natural Philosophy, illustrated by experiments, meeting once a-week, in which the following branches are taught: Mechanics, including statics and dynamics; Hydrostatics, Hydraulics, Pneumatics, and Optics, with such additional matter as time may permit of. A part of every fourth lecture of this course is devoted to examinations on the subjects treated of in the three preceding lectures.

IV. A class of Theoretical Chemistry, in which the principles of the science are taught, together with their application to the principal arts and manufactures in the processes of which chemical principles are involved. This class meets once a-week; and a part of every fourth lecture of this course is devoted to examinations upon the subjects of the three preceding lectures.

V. It is of course left optional to the students to attend as many of the classes in one session as they please, and also to attend them separately in whatever order they prefer. But the directors, impressed with the benefits which may arise from such a course of study, earnestly recommend those who desire fully to avail themselves of the benefits of the institution, to pursue their studies on the following plan, viz. During the *first* year, to attend the junior mathematical class alone; during the *second* year, to attend the senior mathematical and the chemistry classes; and during the *third* year, to attend the natural philosophy and the chemistry classes.

It was therefore with the view of encouraging students to pursue this regular and systematic plan of education, that the directors instituted the honorary certificate above mentioned.

This course of study has for the last four years been most steadily persevered in, and the acquirements of the students who obtained the certificates after the most searching examinations, have completely satisfied the directors and other competent judges who were present on these occasions, that the great object of the institution had, in their case at least, been attained, and that the information acquired by them was sound and practical.

Within the last year an addition to the course of study afforded by this institution has been made, and it promises to have the most beneficial effect on the advancement of those branches of art, in which the principles of *Design* are in any way involved, viz. a class for Ornamental Modelling. It is by no means intended in this class to open a nursery for artists, but only to teach those engaged in trades where ornament is in the least concerned, such as silver-chasers, jewellers, plasterers, glass-cutters, brassfounders, smiths, die-sinkers, and a variety of others, to form their ideas of design on the most approved models of ancient and modern excellence; to enable them, instead of servilely imitating existing patterns, with a vague uncertainty and want of acquaintance with the laws which regulate art, to classify their labours, and, by accustoming their minds to contemplate and imitate acknowledged excellence, gradually to lead the way to that *creative skill* in the execution of designs, which may eventually lead to the commencement of a new era in such departments of art.

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The fee for each of the four classes above mentioned separately, the junior mathematics, the senior mathematics, the natural philosophy, and the chemistry, is five shillings. A ticket which gives admission to all the lectures, twelve shillings. The privileges of the library is extended to all students, whether attending one or more classes.

When these institutions were first originated, a great many excellent persons were led to withhold from them their countenance and support, fearing that the moral effect which they might have on the minds of the working classes would be unfavourable to the reception of those great and fundamental principles of religion, without which all human acquirements sink into insignificance; and that they would only fit their pupils more thoroughly for becoming the dupes and tools of designing men. Our opinion, however, of their effects upon society at large, is very different indeed; for by invigorating the faculties and enlarging the information of the student, this training serves the double purpose of enabling them to understand the evidences and truths of religion more easily and more thoroughly than they could otherwise have done, and of fortifying them more strongly against those sophistries by which its enemies so often and so fatally perplex the ignorant and the simple. It is true that knowledge is not always accompanied with such results; but its natural tendency is to counteract and prevent the very evils which have been apprehended as likely to result from it. Proceeding on the supposition that the young men who attend these institutions have previously, under the parental roof and at the schools where they obtained their elementary education, been taught the principles of religion, the mental discipline which they receive therein, and the course of study they are encouraged to pursue, furnish them with the means of cherishing a more enlightened, vigorous, and steady attachment to those great doctrines, which constitute the perfection and the glory of all science; and as industry is one of the best safeguards of moral conduct, they will operate most beneficially in that respect on those whose chief danger arises from the temptations which beset them at their leisure hours. Being necessarily so much occupied with objects of sense, and so little accustomed to purely mental exercises, when they seek for enjoyment, they are apt to look for it in the indulgence of mere appetite. Now these institutions are calculated to rescue them from the power of such temptations, not only by filling up their spare time with innocent and laudable pursuits, and providing them with occupations which elevate them far above the grossness of sensuality, but by training them up to habits of purity, sobriety, and correct deportment.

It is pleasing, therefore, to be enabled to say that the progress and advancement of the arts since the commencement of these institutions, has been most striking. They have attained an elevation, and partaken of a character which was formerly unknown; and since that period we may date the discovery and improvement of several of the most widely useful inventions, and the consequent dissemination of those comforts and elegancies of life, which have had such an influence on the whole social system.

Mechlin ‖ Mecklenburg.

MECHLIN or MALINES, a circle of the province of Antwerp, in the Netherlands, divided into five cantons and thirty-eight communes, containing 87,800 inhabitants. The capital is the city of the same name, situated in a fertile plain, watered by the river Dyle, and connected by a canal with Louvain. It is the seat of an archbishop, for whom there is a magnificent palace, and a cathedral, with a tower 350 feet in length. Some of the other public edifices are on an extended scale. There is an ecclesiastical seminary, and a convent of Beguines, wherein formerly were 800 professed females; and though the number is now reduced, it is both respectable and useful, as it affords visitors to the poor and the sick, and relief to the distressed, in an extensive and gratuitous way. It contains 3000 houses, and about 20,000 inhabitants, who are very industrious. There are numerous hat-makers, and weavers of woollen cloths and blankets. The most distinguished of the fabrics is that of thread lace of the finest description, which bears the name of the city, and is highly esteemed in every part of the world where it is known. Lat. 51. 15. 2. N. Long. 4. 23. 39. E.

MECHOACAN, a province of Mexico, or New Spain, in America, bounded on the north by Panuco and Guadalajara, on the south by the Pacific Ocean, and on the west by Guadalajara and the South Sea. It is about 200 miles in circumference, and its population in 1793, amounted to 289,314. The soil is exceedingly fertile, and the climate so wholesome, that the Spaniards imagine it possessed of some peculiarly restorative quality, for which reason the sick and infirm flock to it from all quarters. The commodities are sulphur, indigo, sarsaparilla, sassafras, cacao, vanelloes, ambergris, hides, wool, cotton, silk, sugar, the root mechoacan or white jalap, and silver. This province formed an independent kingdom at the time when Mexico was reduced by Cortez. The sovereign had long been the inveterate enemy of the Mexicans, and was considered next to the republic of Tlascala, as the most formidable barrier against the extension of the imperial frontier. However, he submitted to Cortez without striking a blow, being intimidated by the wonders he had performed with a handful of men; and thus Mechoacan became a province of the Spanish empire, and a valuable addition to Mexico. The country at that time was exceedingly populous, but the natives are now much thinned. The capital of the province, called Mechoacan by the natives, but Valladolid by the Spaniards, contained 17,093 inhabitants in 1793.

MECKLENBURG-SCHWERIN, a grand duchy in the north of Germany. It extends from 10. 34. to 12. 20. E. long., and from 53. 8. to 54. 19. N. lat. It is bounded on the north by the Baltic Sea, on the east and south by the Prussian territory, and by the Danish, late Hanoverian, province of Lunenburg. It is a compact duchy, except that some small portions of it are within the Prussian province of Brandenburg, and others in Mecklenburg-Strelitz. It extends over 4924 square miles, and is divided politically into five provinces, in which there are forty-one cities or walled towns, seven market towns, and 621 villages, with, in 1827, 430,928 inhabitants. The population is derived from a tribe of Wendens or Vandals, though they have not retained their old language, but now speak the dialect of German commonly known by the name of *platt Deutsche*. At present the whole of the peasantry are in a state of freedom from the feudal system which once universally prevailed in Europe; but in Mecklenburg it was the longest retained, having been only abolished in 1825. The religion of the duchy is Lutheran, but there are about 1000 Catholics, and 300 Calvinist dissenters, and 3000 Jews, with a few scattered Menonites. The principal river is the Elbe, which receives the waters of five smaller streams, and has on its banks the towns of Domitz and Boitzenburg, by which navigation is carried on upwards to Berlin, and downwards to Hamburg. There are several lakes in the country; that of Schwerin is the most extensive; and for the most part they discharge their waters by small rivers into the Baltic Sea. The face of the country is generally level; much of the soil is sandy, but a part is moderately fertile, and being well cultivated, yields a larger surplus of corn, chiefly wheat, than any other part of Europe of the same extent. Corn and wool are the chief commodities for export. The greater part of the land is occupied by the proprietors; and by the application of marl and the increase of the flocks of sheep, stimulated by the high prices obtained in the markets of Holland, Sweden, and England, cultivation has been much extended. The horses of Mecklenburg are much esteemed, and great pains have been taken to improve the racer, by the introduction of valuable horses and mares from England and other countries. Races, too, have been established of late years, the professed object of which has been to give encouragement to improve the whole race of horses. The government is hereditary in the family of the sovereign, which is asserted to be the oldest reigning house of any in Europe. The Grand Duke is limited in his power by the States, which assemble yearly, to adjust the public accounts, and to recommend new enactments, as well as to attend to local affairs. The income of the Duke consists in a great degree of the domains and royalties, with some taxes on foreign goods, and amounts to about £200,000. The public debt is about £300,000, but by a sinking fund is diminishing. The military, including cavalry, infantry, guards, and artillery, consists of 3500 men, besides which there is a numerous militia or *landsturm*. There are some manufactures of linen and woollen goods, but solely for domestic consumption, and some for the more common articles of every-day use. The foreign trade consists in the exportation of the productions of the land, chiefly from Rostock and Weimar, and in part from Boitzenburg; they consist of corn, wool, wood, bacon and hams, feathers, and corn spirits. The imports are wine, fruits, and colonial wares. The capital is Schwerin, but the ducal residence is at Ludwigslust, or, in summer, at Dahlenburg, a bathing place on the Baltic.

Mecklenburg.

MECKLENBURG-STRELITZ, a grand duchy in the north of Germany. It is composed of two portions of the old duchy of Strelitz and the principality of Ratzeburg, and has some territory intermixed with that of other states. It extends over 796 square miles, and comprehends nine cities and towns, 219 villages, 245 princely domains, and 10,805 houses, with 45,500 inhabitants, chiefly employed in cultivation, who all adhere to the Lutheran church, with the exception of about fifty catholics and 750 Jews. The income of the state amounts to £50,000 annually, chiefly arising from the ducal domains. The public debt is so interwoven with that of Mecklenburg-Schwerin that its exact amount is not known, but by the operation of a sinking fund it is decreasing. The regular forces consists of a battalion of infantry and a division of husars, numbering together 772 individuals. The courts of law for both Mecklenburgs are united. King George III. having married a princess of the house, has connected it with the royal family of England. The capital is the city of Strelitz, with 5350 inhabitants. There are in the duchy mines yielding silver, lead, and iron; the last of these is worked into the various articles for which it is adapted at the several manufactories of the duchy. The only manufactures, besides, are those of linen and the several kinds of leather. The chief foreign trade is by the Rhine with Holland, whence supplies of sugar and coffee, and the other colonial wares are obtained. The duke, in 1817, established a kind of representative legislature of two houses of nobles and burghers. The income of the state is about £188,000 annually; the public debt amounts to £500,000; the annual expenditure is £155,000; and the surplus of income is applied to diminish the debt. The regular troops are 2800, besides which there is a numerous militia or landsturm, in which all males from nineteen to twenty-five years of age are bound to serve.

MEDALS.

Medals. MEDAL denotes a piece of metal in the form of a coin, such as was either current money amongst the ancients, or had been struck upon any particular occasion, in order to preserve to posterity the portrait of some great person, or the memory of some illustrious action. Scaliger derives the word *medal* from the Arabic *methalia*, a sort of coin having on it a human head. But the generally received opinion is that of Vossius, viz. that it comes from *metallum*, metal, of which substance medals are commonly made.

I.—*Utility of Medals in History and other Sciences.*

There are few studies of more importance to history than that of medals; the sole evidence we can have of the veracity of a historian being only such collateral documents as are evident to every body, and cannot be falsified. In modern times these are found in public memoirs, instructions to ambassadors, and state papers of various kinds. Such memorials, however, are subject to various accidents, and, besides, commonly remain in the countries where they are first published, and cannot therefore give to the world at large that perfect and entire satisfaction which ought to be derived from genuine history; and hence more durable and widely diffused monuments are still to be wished for. Such are public buildings, inscriptions, and statues; but these, excepting a few instances of the two last, are always confined to particular countries; and medals alone remain as infallible documents of truth, capable of being diffused throughout all countries in the world, and of remaining to the latest ages.

The first who showed the importance of medals in ascertaining the dates and arranging the order of events in ancient history, was Vaillant, in his *History of the Kings of Syria*, printed at Paris in 1681. By means of medals alone he has been enabled to fix the chronology and important events in the history of the three most ancient kingdoms of the world; namely, Egypt, Syria, and Parthia. Since his time there have been discovered many coins which confirm the accounts he has given. He was followed in this method by Father Hardouin, though with much less success. Hardouin's best work is his *Herodiades*, or series of successors to Herod king of Judæa. The same plan was pursued by Noris in his Treatise on the Syro-Macedonian princes, and by Bayer in his History of Osrhoene, as well as by Froelich in his *Annales Regum et Rerum Syriæ*, Vienna, 1754, and Kevenhuller's *Regum veterum Numismata Anecdota, auctore Perrara*, Vienna, 1752, 4to, of which Froelich was properly the author. Corsini and Cary likewise published works of a similar nature; that of the former appeared in 1744, under the title of *De Minnisari, aliorumque Armeniæ Regum, Nummis;* the latter published, in 1752, *Histoire des Rois de Thrace, et du Bosphore Cimmérien, eclaircie par les Médailles.*

The study of the Greek coins does not show the dates of events, though it illustrates the chronology of reigns. This defect, however, is abundantly supplied by those of Rome, which commonly mark the date of the prince's consulship, and the year of his tribunician power; giving also, upon the reverse, the representation or poetical symbol of some grand event. The year of the tribunician power is sometimes imagined by antiquaries to be synonymous with that of the emperor's reign; but this is not the case; and Mr Pinkerton is at some pains to set them right in this respect. He finds fault with Julius Cæsar, when he assumed the sovereign authority, for taking upon him the title of Perpetual Dictator, as being synonymous with that of king or absolute governor, which the Romans abhorred. "He ought," says our author, "under the disguise of some supreme magistracy of annual election, to have lulled the people with a dream that they might terminate his power when they pleased, or that he himself would resign it when the necessities of state, which had required his temporary elevation, had subsided." To this error Mr Pinkerton ascribes the assassination of the dictator, and commends the policy of Augustus, who, with far inferior abilities, continued in possession of the most absolute authority as long as he lived. The tribuneship was an office of annual election, and, if put into the hands of any others than plebeians, must have been the supreme power of the state, as it belonged to that office to put a negative upon every public measure whatsoever. Augustus, being of senatorial rank, could not assume this office; but he invested himself with the tribunician power, which had the advantages of appearing to be only a temporary supremacy, though in truth it was continued during his whole lifetime. Towards the end of his reign, he frequently assumed his intended successor, Tiberius, as his colleague, though in the beginning he had enjoyed it alone. This, with the artifice of resigning his power every ten years, and re-assuming it at the desire, as was pretended, of the senate, secured his sovereignty as long as he lived. His example was followed by his successors; so that most of them have the inscription *Tribunicia Potestate* upon their medals, with the date affixed to it; thus, *Tr. Pot.* VII. Yet though this date generally implies the year of the emperor's reign, it sometimes happens that the emperor, by special favour from a former prince, had been endowed with this title before he came to the throne, as being the successor to that prince; of which we have already given an instance in Tiberius. Besides the tribunician power, the emperors very frequently enjoyed that of the consuls; and the date of their consulship is frequently expressed in their coins.

The office of Pontifex Maximus was likewise assumed by the Roman emperors, in order to secure themselves in their authority; an artifice which, Mr Pinkerton observes, was one of the most efficacious they could have fallen upon. "In the Greek heroic times," says he, "king and priest were carefully united in one person; and when sovereigns arose in Denmark and Sweden, the same plan was followed, as appears from Snorro and other writers. Nothing could lend more security to the person of the monarch than an office of supreme sanctity, which also confirmed his power by all the terrors of superstition. Even the Christian system was afterwards debased by a mock alliance with government, though it be clear from the whole New Testament that such an alliance is subversive of its genuine institution, and the greatest of all its corruptions. But the Roman Catholic clergy, in the dark ages, were the authors of 'no church, no king,' for their own interest; whilst the Roman emperors only sought to strengthen their power by the mystic awe of superstition. The title of Pontifex Maximus was so important, that it was retained even by the Christian emperors till the time of Gratian. Its influence in the state was indeed prodigious. Cicero observes, that to this office were subject temples, altars, penates, gods, houses, wealth, and the fortune of the people." That of augur is also borne by many emperors; and its authority was such that, by the law of the twelve tables, no public business could be transacted without a declaration from the augur concerning its event. The proconsular power was also given to Augustus and the other emperors. It conferred a direct authority over all the provinces, and

Medals.

Medals. implied that the emperor was chief proconsul or governor of each and of all. Another special power assigned to the emperors, but not occurring on coins, was the *Jus Relationis Tertiæ, Quartæ,* &c. or the right of making three or four motions in the senate on the same day, whilst the senators could only propose one.

Hence it has been inferred that medals afford the most authentic documents of the Roman history, in particular, that could have been invented by man. The histories of Nerva and Trajan are much better elucidated by medals than by authors; for the history of Suetonius ends with Domitian, and the *Historiæ Augustæ Scriptores* begin with Hadrian; so that the reigns of the two emperors just mentioned are almost unknown, and Mr Pinkerton is surprised that none of the learned have attempted to supply the defect. "Capitolinus," says he, "in his life of Maximinus Junior, is quite puzzled to know if Maximus and Pupienus were two emperors, or two names for the same. Had he happened to consult any of those coins which bear M. Cl. Pupienus Maximus Aug. he would have seen at once that Maximus was only another name for Pupienus."

Medals are useful in other sciences besides history. In geography, we find the situation of towns determined by their vicinity to some noted river, mountain, or other physical object. Thus, ΜΑΓΝΗΤΩΝ ΣΙΠΥΛΟΥ shows that Magnesia is situated under Mount Sipylus. In like manner, it is shown from a medal that Ephesus stood on the river Cayster; and there is extant a medal bearing an inscription which signifies Alexandria on the Scamander, a name given to Troy by Alexander the Great. The reverse has upon it the famous Apollo Smintheus of Homer. In natural history, also, medals are useful chiefly from the coins struck on the celebration of the secular games, in which the figures of various animals are preserved; and thus it may very often be determined whether any animal was known to the ancients or not. On many of the Greek medals are several uncommon plants and animals. Thus, on most of the medals of Cyrene is the figure of the celebrated *Syphium;* and on those of Tyre, the shell-fish from which the famous Tyrian purple was procured. By means of medals, also, the exact delineations of many noble edifices are preserved, though not even a vestige of their ruins be now in existence; so that the uses of them to the architect are very considerable. To the connoisseur they are absolutely necessary; because by them alone he is enabled to ascribe ancients busts and statues to their proper persons, with multitudes of other points of knowledge which cannot be otherwise determined. The elucidations of obscure passages in ancient authors, by means of medals, are so numerous and well known that it is needless to insist upon them.

Mr Addison has treated the connection between medals and poetry at considerable length; but Mr Pinkerton finds fault with him for preferring the Latin to the Greek poets. He observes, also, that the knowledge of Greek medals is most necessary for a sculptor, and perhaps an architect; but an acquaintance with Latin ones is preferable for a poet, or perhaps a painter. The reason of this difference is, that the former generally have on the obverse the head of some king, god, or goddess, of exquisite relief and workmanship; but the reverse seldom exhibits much fancy of symbol in the early Greek coins, and in the imperial Greek coins is chiefly impressed with the temples of their deities. To a person of poetical imagination, however, the Roman coins afford the greatest entertainment, from the fine personifications and symbols to be found on their reverses. Of this the following are instances.

Happiness has sometimes the caduceus or wand of Mercury, which, Cicero tells us, was thought to procure every wish. She has, in a gold coin of Severus, heads of poppy, to express that our prime happiness consists in the oblivion of misfortune. Hope is represented as a sprightly girl, Medals. walking quickly, and looking straight forward. With her left hand she gathers up her garments, that they may not impede the rapidity of her pace; whilst in her right hand she holds forth the bud of a flower, an emblem infinitely finer and more poetical than the trite one of an anchor, which is the symbol of Patience, and not of Hope. This personification, with some others, must have been very familiar to the ancients; for often in this, and in a few more instances, no name, as Spes Aug. or the like, is inserted in the legend. Abundance is imagined as a sedate matron, with a cornucopiæ in her hands, of which she scatters the fruits, and does not hold up her cornucopiæ and keep the contents to herself, as many modern poets and painters make her do.

The Emperor Titus having occasion to import a great supply of corn during a scarcity at Rome, that supply, or the *Annona*, is finely represented as a sedate lady, with a filled cornucopiæ in her left hand, which she holds upright, to indicate that she does not, however, mean to scatter it, as Abundance has a title to do, but to give it to Equity to deal out. This last particular is shown by her holding a little image of Equity, who is known by her scales, and *hasta pura*, or pointless spear, in her right hand, over a basket filled with wheat. Behind the *Annona* is the prow of a ship decked with flowers, to imply that the corn was brought by sea (from Africa), and that the ships had had a prosperous voyage. The best poet in the world could scarcely have given us a finer train of imagery; and the best painter might have been puzzled to express so much matter in so small a compass.

Security stands leaning upon a pillar, indicative of her being free from all designs and pursuits; and the posture itself corresponds to her name. Horace, in describing the wise man, mentions his being *teres atque rotundus*, round and polished, against all the rules of chance; an idea seemingly derived from the column upon which this ideal lady reclines. The emblems of Piety, Modesty, and the like, are equally apposite and poetical.

The happiness of the state is pictured by a ship sailing before a prosperous breeze; an image than which the exquisite genius of Gray could find none more appropriate, and he has accordingly used it in his principal production, The Bard, with due success.

The different countries of the then known world are also delineated with great poetical imagery. It affords patriotic satisfaction, in particular, to a Briton, to see his native island often represented upon the earliest imperial coins, sitting on a globe, with a symbol of military power, the *labarum*, in her hand, and the ocean rolling under her feet; an emblem almost prophetic of the vast power which she was destined afterwards to obtain by establishing her dominion over the sea.

Coins also present us with Achaia, Africa, Alamannia, Alexandria, Arabia, Armenia, Asia, Bithynia, Cappadocia, Dacia, Dardania, Egypt, Gallia, Hispania, Italia, Judæa, Macedon, Mauritania, Pannonia, Parthia, Phrygia, Sarmatia, Sicily, Scythia, Syria, and the rivers Danube, Nile, Rhine, Tiber. This personification of provinces seems to have arisen from the figures of provinces carried in triumphs; as the personification of our old poets sprung from the ideal persons actually represented in the mysterial plays. There is one colonial medal, rudely executed, of Augustus and Agrippa, which has a high claim to merit in displaying the ancient poetical imagery. It is inscribed Imp. and Divi. f.; and on the reverse the conquest of Egypt is represented by the metaphor of a crocodile, an animal almost peculiar to that country, and at that period esteemed altogether so, which is chained to a palm tree, at once a native of the country and a symbol of victory.

As the reverses are so useful for knowledge of personi-

Medals. fication, symbols of countries and actions, and the like, so the portraits to be seen on old coins are no less important to a painter, the high merit of a great number of them, in every character, justly entitling them to be regarded as the best studies in the world; not to mention that, to an historical painter, the science of ancient medals is absolutely necessary, that he may delineate his personages with the features which they really bore whilst in existence. This can only be attained in the way here mentioned, or from statues and busts, any one of which will cost as much as hundreds of medals; and indeed a collection of such is only attainable by princes.

The same circumstances which render the study of medals important to a painter, do still more so to a sculptor; and, in this particular, the study of the Greek coins is remarkably useful. The skill of the Greeks in the art of sculpture has always been admired throughout the world; and on their coins the heads of several deities are represented in the most exquisite *alto relievo*. Pinkerton, therefore, thinks it strange that the Grecian coins should have hitherto been so little attended to by men of learning and taste. They may have been looked upon, he supposes, as belonging only to the province of the antiquary; but he assures us that the Greek medals will afford satisfaction to the persons who value them only as pieces of workmanship. In most respects they greatly excel those of Rome, even in its best times, which is usually supposed to have been from the days of Augustus to Hadrian. In the days of Hadrian, in particular, the Roman mint seems to have been the very seat of art and genius; witness the vast number of exquisite personifications, engraved with equal workmanship, which swarm on the medals of that prince. Yet from his time down to Posthumus, coins of admirable workmanship are to be found. Those of the Faustinas and Lucilla deserve particular mention. There is one, and not an uncommon one, of the latter, in great brass, which yields to nothing of the kind. The reverse is a Venus, with the name around her. The portrait of the obverse seems to spring from the field of the coin; it looks and breathes, nay talks, if you trust your eyes. The coins of Tarsus are, as Froelich observes, extremely remarkable for a kind of perspective in the figures. On others are found triumphal arches, temples, fountains, aqueducts, amphitheatres, circuses, hippodromes, palaces, basilicas, columns and obelisks, baths, sea-ports, pharoses, and the like. These furnish much pleasure and instruction to the architect, and serve to form his taste to the ancient manner; that manner which unites perfect simplicity with sublimity and grace, and which every age admires, in proportion as it has genius to imitate.

II.—*Entertainment arising from the Study of Medals.*

Besides the purposes which the study of medals answers in the useful arts, a great variety of sources of entertainment are to be found in it. Mr Pinkerton observes, that the most barbarous nations are more pleased with the rudest efforts of art than with the most admirable works of nature; and that in proportion as the powers of the mind are large and various, such are also the pleasures which it receives from those superlative productions of art, which can only be the offspring of great genius. Hence works of art are agreeable both to the enlightened and to the ignorant. The chief amusement, therefore, which attends the study of medals, originates from the strength and spirit, the finish and beauty, which the engraver has displayed in the execution of them. It besides gives a kind of personal acquaintance with the individuals of whom they are the representations. Portraits have always been highly entertaining to mankind; and Pinkerton is of opinion that the love of them gave rise both to painting and sculpture. They are nowhere to be found so ancient, so numerous, and so well preserved, as in medals. Amusement is also derived even from the representations of ideal heads and persons; nay, even from the minutest symbols. Thus the Greek coins of cities present us with heads of deities of exquisite workmanship, apparently copied from statues or paintings; so that we may even guess at the works of Apelles and Praxiteles from some of the Greek medals. Their reverses exhibit still greater variety, there being scarcely an object either in art or nature which is not represented upon some of them; and to the satisfaction arising from a view of these we may likewise add that of beholding, in a lively manner, the dresses, manners and customs, religious and civil ceremonies, of the ancients; so that from medals we may obtain an interesting history of manners, which, though but lately cultivated, may perhaps become the most useful and entertaining of all the provinces of history. Medals.

There is a very considerable difference between the study of medals and that of a mere antiquary. The latter seems frequently to take delight in coins merely in proportion to their rust and deformity; so that it is often a recommendation of some of their pieces that neither portrait, reverse, nor legend can be discovered, at least in such a manner as may be intelligibly explained. "The delight of the antiquarist," says Mr Pinkerton, "may be called a depraved appetite of the mind, which feeds on trash, and fills itself with emptiness. It is perhaps a mere childish curiosity mingled with caprice and hypochondricism. Against this character the ridicule of Severus is particularly shot, but with little effect; for our antiquists exceed in visions and nonsense. I say *antiquists*, for the name of antiquary is sacred. By *antiquary*, in foreign countries, is implied a man who illustrates their ancient laws, manners, poetry, but especially their ancient history. There, men of the most elevated minds are antiquaries; as Muratori, Leibnitz, Montesquieu, Dubos. Here, men of talents will not stoop, forsooth, to studies the most important to their country, but leave its antiquities to chance. Every thing is important but our history; and we are profound in every ancient matter that is superficial, and superficial in what is profound. Even England cannot boast of one general historian, but trusts to the inaccuracy of Rapin and the ignorant neatness of Hume. It is therefore no wonder that the study of antiquity is here ridiculous, though most important in other countries; none requiring greater talents, learning, or industry. But the historic antiquary has the pleasure of benefiting society, and enlightening whole nations, while the medallic has only an innocent amusement. This amusement, considered merely as arising from antiquarian objects, has not been explained, though felt by most people, and more by the learned. It seems analogical with that which we derive from an extensive prospect; for as the mind delights to expand itself into distant places, so also into distant times. We connect ourselves with these times, and feel as it were a double existence. The passions are singularly affected by minute circumstances, though mute to generalities; and the relics of antiquity impress us more than its general history."

III.—*History of Medals.*

The study of medals is not of very ancient date. None of the classical writers gives any account of collections of them, though indeed many little particulars are passed without notice by them. In the times of the Greeks, a collection of such coins as then existed must have been but little regarded, as consisting only of those struck by the numerous little states which at that time used the Greek characters and language. Hence they would have

Medals. had an air of domestic coinage, and no attention would have been paid to them, however exquisite their workmanship might have been. The little intercourse at that time carried on between the different provinces, also, greatly impeded any communication of knowledge to those who wrote histories; so that it is no wonder to find any small collections which might then have existed altogether unnoticed by them.

Almost as soon as any communication was opened between the Greeks and Romans, the latter treated the arts of the Greeks with all due respect and applause. Their coins were imitated by the Romans, and preserved in cabinets by the senators amongst their choicest treasures. Suetonius informs us, that on solemn occasions Augustus was accustomed to present his friends with medals of foreign states and princes, along with other valuable testimonies of his friendship. In a more advanced period of the Roman empire, however, individuals would undoubtedly form collections of coins peculiar to their own state; for Dr Stukeley, in his Medallic History of Carausius, informs us that a complete series of silver coins was lately found in Britain, containing all the emperors down to Carausius inclusively. From Banduri we also learn that certain Greek coins were specially preserved by the Romans; and it appears from their code, that ancient gold and silver coins were made use of instead of gems, to which distinction those of Sicily were particularly entitled. From the decline of the Roman empire until towards the end of the fifth century, almost all branches of literature were involved in darkness, and the science of medals amongst the rest. Whilst the Christian dominion of Constantinople lasted, indeed, almost all the arts and sciences may be said to have been confined within its boundaries, though the Arabs and eastern nations had some arts and sciences of their own; but after the destruction of the imperial city by the Turks, the Greeks were once more compelled to become the fathers of European science. Even before this time, indeed, some vestiges of a revival of literature had appeared in Italy; and so intimate and necessary a connection has now the study of medals with that of ancient erudition, that on the earliest appearance of a revival of the latter, the former was also cultivated.

The first amongst the moderns who began to study the science of medals was Petrarch. Being desired by the emperor Charles IV. to compose a book containing the lives of eminent men, and to place him in the list, he replied that he would do so whenever the emperor's life and conduct deserved it. In consequence of this conversation, he afterwards sent the emperor a collection of gold and silver coins bearing the representations of eminent men, with an address suitable to his former declaration. A collection of coins was made in the next age by Alphonso king of Aragon; but though this monarch collected all that could be found throughout Italy, we know that there could not have been very many, as the whole were contained in an ivory cabinet, and carried always about with him. A very considerable collection was made by Anthony Cardinal St Mark, nephew to Eugene IV. who ascended the pontifical chair in 1431; and soon afterwards the grand museum at Florence was begun by Cosmo de' Medici, where a collection of ancient coins and medals had a place amongst other curiosities. Corvinus king of Hungary about the same time formed a noble collection of coins, along with ancient manuscripts and other valuable relics of antiquity.

Mr Pinkerton considers Agnolo Poliziano, more commonly known by the name of *Angelus Politianus*, as the first writer who produced medals as vouchers of ancient orthography and customs. He cites different coins of the Medicean collection in his *Miscellanea*, written about the year 1490. By means of a cabinet of medals which had been formed by Maximilian I. emperor of Germany, Joannes Huttichius was enabled to publish a book of the lives of the emperors, enriched with their portraits delineated from ancient coins. It is generally supposed that this book, which appeared in 1525, was the first work of this kind; but Labbé, in his *Bibliotheca Nummaria*, mentions another named *Illustrium Imagines*, by one Andreas Fulvius, printed in 1517, in which most of the portraits seem to be from medals. About the year 1512, also, Guillaume Bude, a French author, had written his treatise *De Asse*, though it was not printed till many years afterwards. M. Grollier, treasurer of the French armies in Italy, during part of the sixteenth century, had a great collection of coins of different kinds of metals. After his death his brass medals were sent to Provence, and were about to be conveyed to Italy, when the king of France, having got information of the transaction, gave orders to stop them, and purchased the whole at a very high price, for his own cabinet of antiquities. M. Grollier had an assortment of gold and silver as well as of brass medals; but the cabinet in which they were contained fell, two centuries afterwards, into the hands of M. l'Abbé de Bothelin, and was known to have been that of Grollier, from some slips of paper, on which was his usual inscription for his books, *Joannis Grollierii et amicorum.* There are few countries, Italy excepted, in which a greater number of coins have been found than in Britain; though we are by no means well acquainted with the time when the study of them commenced. Mr Pinkerton suspects that Camden was one of the first, if not the very first British author, who produced medals in his works, and who must have had a small collection. Speed's Chronicle, published in the seventeenth century, was illustrated by means of coins from Sir Robert Cotton's cabinet.

IV.—*Materials of which Medals are constructed.*

Medals are formed of gold, silver, and the various modifications of copper. The gold usually made use of in coinage is about the fineness of twenty-two carats; and as the art of purifying this metal was very imperfectly known in former times, the most ancient medals are for this reason much more impure than the modern coins. Gold is never found in its native state above twenty-two carats fine; and the very ancient medals are much under that standard. Many of them are composed of a mixture of gold and silver, called by the ancients *electrum*. The gold medals were made of much finer metal after Philip of Macedonia became possessed of the gold mines of Philippi in Thrace; and the medals of his son Alexander the Great are equally fine, as well as those of some other princes of that age. Those of the Egyptian Ptolemies are of the fineness of twenty-three carats three grains, with only one grain of alloy. The Roman coins are very pure even from the earliest times; the art of refining gold having been well known before any was coined at Rome. Some authors are of opinion that the Roman coins begin to fall short of their purity after the time of Titus; but Mr Pinkerton denies that any thing of this kind took place till the time of the emperor Severus, and even then only in a very few instances. Most of the Roman gold was brought from Dalmatia and Dacia, where that metal is still to be met with.

Pliny informs us, and indeed it is generally known, that gold and silver are found mixed together in the earth. Where the silver amounted to one fifth part of the gold, the metal was called *electrum*; but sometimes the proportion of silver was added artificially. The gold was in those days, as well as at present, refined by means of mercury; and the ancient artists had certainly attained to great perfection in this branch of metallurgy, as Bodin tells us that the goldsmiths of Paris, upon melting one of Vespasian's gold coins, found only $\frac{1}{788}$th part of alloy.

Medals. Most of the ancient silver, particularly that of Greece, is less pure than that of succeeding times; even the Roman silver is rather inferior to the present standard, and that from the very beginning; but in the time of Severus the silver appears to have been very bad, and it continued so until the time of Diocletian. Many writers upon this subject have mistaken the *denarii ærei*, coins of brass washed with silver, for silver currency. Silver coins are extremely scarce from the time of Claudius Gothicus to that of Diocletian, or from the year 270 to 284, in which short space not fewer than eight emperors reigned. Silver at that time was found mostly in Spain, and the commerce with that country was disturbed by the usurpers who arose in Gaul; and such were the troubles of the times, that not only the silver, but also the gold coins, of those emperors, are extremely scarce. There is still, however, some silver extant of those eight emperors; and it is certain that copper washed was never used as silver currency, but was entirely a distinct coinage. Occasional depravations of silver had taken place long before, as Pliny tells us that Mark Antony mixed iron with his silver denarii; and Mr Pinkerton informs us that he had seen a denarius of Antony which was attracted by a magnet.

The ancient brass coins consist of two kinds; the red or Cyprian, which indeed is no other than copper; and the common yellow brass. Our author observes that, in the Roman coinage, brass was of double the value of copper, and he is of opinion that it was the same amongst the Greeks; but the latter is the metal most commonly made use of in the Greek coinage. The Roman sertertii were always of brass, the middling-sized kind are partly copper and partly brass; the former being double the value of the latter, which are the *asses*.

Mr Pinkerton next proceeds to give an account of the mixed metals used amongst the Romans. In Britain, all kinds of coins made of mixed metal are without hesitation alleged to be forgeries; although it is certain that the variety of mixed metals used in coinage was very considerable. The most valuable mixture was that of gold and silver, already mentioned under the name of *electrum*; the silver commonly amounting to one fifth part of the gold made use of, or perhaps more. Of this mixture are many of the early coins of Lydia, and some other Asiatic states; also those of the kings of the Bosphorus Cimmerius during the imperial ages of Rome. Next to the electrum were the coins of Corinthian brass; but Mr Pinkerton informs us that not a single coin was ever struck of this metal by the ancients, it having been constantly employed only in the fabrication of vases or toys. It was in use, at any rate, only for a very short time, being altogether unknown in the days of Pliny the Elder. This author therefore ridicules those who pretend not only to find out imperial coins of this metal, but to discover three kinds of it, viz. one in which the gold predominates, another in which the silver prevails, and a third where the brass is most conspicuous. He gives Æneas Vico, one of the most ancient writers on medals, as the author of this idea, but whose opinions were confuted by one Savot, a writer in the seventeenth century. Vico mentions a coin of this kind struck under Augustus, another of Livia, and a third of Claudius. The mistake, he is of opinion, arose from the circumstance of the first propagator not being able to account for the various mixtures and modifications of brass observable in ancient coins of the large size, and which in so common a metal appear very odd to the moderns. Besides the authority of Pliny and other antiquaries of a more modern date, who all declare that they never saw a single medal of Corinthian brass, or of that metal mixed with silver and gold, Pinkerton produces another evidence, which he looks upon as superior to either, viz. that those who have given in to this supposition imagine that the large pieces called *sertertii*, and others called *dupondiarii*, worth about two-pence or a penny, are said to have been composed of this precious metal. But it is unreasonable to think that any portion of gold or silver could have been made use of in these. The coins said to have been struck upon Corinthian brass are only done upon a modification of common brass, in regard to which we know, that in proportion to the quantity of zinc made use of in conjunction with the copper, the metal assumes a variety of hues. On the authority of Pliny, he informs us that the coins mistaken for Corinthian brass were no other than prince's metal. Medals.

The Egyptian silver coins struck under the Roman emperors are at first of tolerably pure silver, but afterwards degenerate into a mixture of copper and tin with a little silver. They are very thick, but many of them are elegantly struck, with uncommon reverses. There are likewise three sets of brass coins belonging to this country from the earliest times of the Roman emperors. Some of these are of bell-metal or pot-metal; but after the time of Gallienus and Valerian, the coinage of brass with a small addition of silver became authorized by the state, the coins struck upon it being called *denarii ærei*. Those of lead or copper plated with silver have been fabricated by Roman forgers. Some coins of lead, however, have been met with of undoubted antiquity; and an ancient writer informs us that tin money was coined by Dionysius; but none has been found. The lead coins of Tigranes, king of Armenia, mentioned as genuine by Jobert, are accounted forgeries by Mr Pinkerton and other modern medallists. Plautus, however, makes mention of leaden coins, and several of them have been found; but Pinkerton looks upon them as having been chiefly essay pieces, struck in order to let the artist judge of the progress of the die. Others are the plated kind already mentioned, fabricated by ancient forgers, but having the plating worn off. A great number of leaden coins are mentioned by Fricorini, in a work entitled *Piombi Antichi*, in which he supposes them to have served as tickets for guests; and coins of the same kind are also mentioned by Passeri. In the work entitled *Notitia Imperii Romani*, there is mention made of coins of leather; but none of them has ever been found.

V.—*Of Ancient Money.*

In considering the different sizes, values, &c. of the Greek and Roman coins, Mr Pinkerton treats of the medals as money; a knowledge of which, he says, is essentially necessary to every reader of the classics, insomuch that it may almost dispute the preference with the studies of ancient geography and chronology. Notwithstanding all that has been written upon the subject, however, the same writer is of opinion that the science is still in its infancy, in as far as it relates to the real money of the ancients. "The ideal," says he, "which is indeed the most important province of discussion, has been pretty clearly ascertained; and we are almost as well acquainted with the Attic *mna* or *mina*, and the perplexing progress of the Roman *sestertia*, as with our own *pounds*. But with the actual coin of the ancients the case is different; and the ignorance of the learned even in this point is wonderful."

He then proceeds, with very great asperity of language, to particularize the ignorant manner in which modern authors have treated the subject of medals. "Arbuthnot and Clarke," says he, "are, if possible, more ignorant of medals than Budæus, the very first. The latter professes his love of medals, but quotes a consular coin with the head of Cicero; and looks upon one of the thirty pieces of silver, the reward of the treachery of Judas, and which was said to be preserved among some relics at Paris, to be worthy of reference and commemoration. Arbuthnot, if we may judge from his book, had never seen any ancient coins;

Medals. and Clarke, it is well known, was quite ignorant of them. The latter, with all his labour, seems even to have known nothing of the theoretic part of the real ancient money. Indeed, Dr Mead's catalogue seems to have been almost the only book on medals which had undergone his perusal. On the other hand, the ignorance of medallists on this score is no less profound. To this day they look upon the *didrachms* of Ægina, so celebrated in antiquity, as *tridrachms* of Ægium; and upon the early obolus as a brass coin. In the Roman class the large brass is esteemed the *as*, while it shall be proved that it is the *sestertius*, and worth four *asses*. The *denarius* is reckoned at ten asses, even in the imperial times, whereas it only went at that rate for the first ninety years after the coinage of silver at Rome. The denarius æreus is taken for silver currency; with other mistakes, which evince that medallists are as ignorant of the theory as the others are of the practice."

In his account of the ancient Greek money, Mr Pinkerton observes, that the light of science, like that of the sun, has proceeded from the east to the west. "It is most probable," says he, "that the first invention of money arose like the other arts and sciences, and spread from thence into the western parts of the world. In its first shape it appeared as mere pieces of metal, without any stated form or impression, in lieu of which it was regulated by weight. Even down to the Saxon government in England, large sums were regulated by weight; and in our own times every single piece is weighed in gold; though with regard to silver this nicety is not minded, nor indeed does it seem practicable. Amongst the ancients, whose commercial transactions were less important and extensive than those of the moderns, silver was weighed as well as gold; nay even brass in some cases."

In Greece, small sums were determined by *mnæ* or *minæ*, and large sums by *talents*. In every country the mina is supposed to have contained a hundred drachmæ or small silver coins of that country, and the talent sixty minæ. The mina is supposed to be a pound weight of the country to which it belonged. The Attic pound, according to Dr Arbuthnot, contained sixteen ounces, equal to our avoirdupois pound; but Mr Pinkerton looks upon this as a very absurd opinion, and accuses the doctor of having adopted it merely that he might explain a passage in Livy. He is of opinion that the Attic pound is very nearly the same with the pound Troy. The mina of Athens had at first only seventy-three drachms; but by Solon it was fixed at a hundred. The ancient drachm weighed the same which it does at present in medical weight, viz. the eighth part of an ounce. The mina or pound of twelve ounces had consequently ninety-six of these drachms; but four of them were given to the round sum to supply defects in the alloy, in consequence of a practice common in all ages and in all countries, of giving some addition to a large weight. Thus the pound in weight had but ninety-six drachmæ in fact, whilst the pound in tale had a hundred; as the Roman libra in weight had but eighty-four denarii, in tale a hundred and eight; and as our pound in tale, by an inverse progress, is not a third of our pound in common weight.

Notwithstanding the severe criticism on Dr Arbuthnot just mentioned, however, we find Pinkerton adopting his account of the *talents* used in coinage in several countries. Thus, according to the doctor,

The Syrian talent contained	15	Attic minæ.
Ptolemaic	20	
Antiochian	60	
Eubœan	60	
Babylonian	70	
Larger Attic	80	
Tyrian	80	
Egyptian	80	
The Æginean	100	Attic minæ.
Rhodian	100	

Medals.

Notwithstanding the concession made here by Mr Pinkerton to the doctor, he tells us that he very much questions this list of talents, and that many ancient writers are little to be relied upon. Writers on this subject confess that the numbers in all ancient manuscripts are the parts most subject to error, as being almost always contracted. They ought to allow that the authors themselves must often be liable to wrong information.

"Herodotus mentions that King Darius ordered gold to be paid into his treasury by the Euboic talent, and silver by the Babylonian. The Euboic is esteemed the same with that called afterwards the Attic; and as we estimate gold by carats, so it is natural to suppose that the most precious metal would be regulated by the most minute weight. But I confess I take the Babylonic talent to be the same with that of Ægina. Mr Raper has proved the first coins of Macedon to be upon the standard of Ægina. Now the early Persian coins are upon that very scale, the largest tetradrachms weighing from 430 to 440 grains. Hence it follows that the Persian silver coins were of the Æginean standard, and the payment was certainly to be made according to the standard of the money. The larger Attic talent was of 80 lesser minæ, because the larger Attic mina was of 16 ounces. The Alexandrian talent, according to Festus, consisted of 12,000 denarii, being the same with that used by the Egyptian kings in their coins; and it is shown by Mr Raper to have been the same with the talent of Ægina. Perhaps the whole of the ancient coins of Asia, Africa, Greece, Magna Græcia, and Sicily, are reducible to three talents or standards: 1. That of Ægina, used in most of the more ancient silver coinages, as would seem in even the later of Egypt, Carthage, Cyrene, &c.; 2. the Attic (being the Asiatic gold standard, afterwards used by Phidon king of Argos in estimating gold, and called Euboic from Eubœa, one of the quarters of the city of Argos), used in Athens and the greater part of the world as the standard both of gold and silver; 3. the Doric or Sicilian talent of twenty-four nummi, each worth an obolus and a half, whence the talent is estimated at six Attic drachms, or three darics. These weights continued to be the standard of money after it began to be distinguished by impression; nay, until the fall of Greece and prevalence of the Roman empire." Thus far Mr Pinkerton.

Coinage, according to Herodotus, was first invented by the Lydians, from whom the Greeks quickly received it. The former could not have received it from the Persians, whose empire did not begin till 570 B. C., though our author supposes that it might have proceeded from the Syrians, who carried on commerce in very ancient times. The most ancient Greek coins of silver have an indented mark upon one side, and a tortoise upon the other; and those of the greatest antiquity have no letters upon them. Those of later date have AIΓI marked upon them, which medallists interpret of Ægium in Achaia; being led into that supposition by the tortoise, which they look upon as a sure mark of the Peloponnesus. But though Pinkerton agrees that the tortoise was so, he thinks that they are otherwise very far wrong in their conclusions. Ægium in Achaia was a place of no consequence till the times of Aratus and the Achæan league; but there are eleven of these coins in Dr Hunter's cabinet which show that they must have been struck in times of the most remote antiquity, and that the place where they were struck was rich and flourishing at the time. The coins we speak of are not common; but those which have the name AIΓEIΩN at full length, and which may perhaps belong to Ægium in Achaia, are extremely scarce; insomuch that in all Dr Hunter's vast collection there are not above one or two. They are likewise constructed upon a scale quite different

Medals. from all other Grecian money, being of 8, 13, 15½, 90, and about 186 grains. The Grecian drachma at an average is 66 grains; and Mr Pinkerton thinks it would have been strange if pieces had been struck of eight tenths of an obolus, of an obolus and a half, or of a drachma and a half. Ægium being originally an obscure village, could not be the first which coined money; so that Mr Pinkerton supposes the name AIΓI to have stood for Ægialus, the ancient name of Sicyon, a wealthy and powerful city; or rather Ægina, the mint of which was much celebrated, and perhaps the most ancient in Greece.

Other arguments in favour of these coins being derived from Ægina, are drawn from their weight as well as their workmanship, which are quite different from those bearing the name of Ægium at full length. The coinage of Ægina is known to have been different from that of the rest of Greece; insomuch that its drachma was worth ten Attic oboli, whilst the Attic drachma was valued only at six. Hence the drachmas of Ægina were named by the Greeks παχειαι, or *thick*; a name very applicable to the coins in question. From these observations, Pinkerton is of opinion that we may even distinguish the precise weight of the ancient coins of Ægina. According to the exact proportion, the drachma of this place should weigh exactly a hundred grains; and one of them very much rubbed weighed above ninety. The others of larger size, which seem to be didrachms of Ægina, weigh from a hundred and eighty-one to a hundred and ninety-four grains; but the latter being the only one he could meet with in good preservation, it was impossible to form any just medium. Even in those which are best preserved, he thinks that ten grains may be allowed for a waste of the metal in so long a time as 2400 years, which would bring the drachma of Ægina near its proper standard. The obolus of Ægina was in proportion to its drachma of six oboli. It is the piece of fifteen and a half grains, and thirteen when very much rubbed. The hemiobolion is that of eight, but when rubbed it falls short of this weight.

The general denomination of the Greek money is the drachma, or eighth part of an ounce, which to this day is retained in the medical weights; the Grecian coins receiving the names they bore from their weights, though in some instances the weights received their appellations from the coins. The silver drachma, according to Mr Pinkerton, was about ninepence sterling; and he finds fault with those who make the drachma and denarius both equal to one another, the latter being no more than eightpence. The didrachm of silver, according to the same calculation, was worth 18d.; but the tridrachm occurs very rarely, and Mr Pinkerton is even of opinion that medallists give this name to the didrachm of Ægina. The largest of all the Grecian coins is the tetradrachm, which on the Æginean standard is worth five shillings, but in those of the other states only four. There are, however, many subdivisions in the silver drachma, the highest of which is the tetraobolion or coin of four oboli; being in proportion to the drachma as our groat to a sixpence, weighing about forty-four grains, and being in value about sixpence. The hemidrachm or triobolion comes next in value, weighing about thirty-three grains, and worth fourpence halfpenny. The silver diobolion, or third of the drachma, weighs about twenty-two grains, and is worth threepence. The obolus of silver weighs about eleven grains, and is worth only three halfpence. There is likewise a hemiobolion in silver, or half the obolus, of five grains and a half, value three farthings; and another called *tetraobolion dichalcos*, or quarter obolus, which is the most minute coin yet met with, and, by reason of its extreme smallness, weighing only two grains and a quarter, is now very scarce. There is one of these in the cabinet of Dr Hunter, and some more were brought from Athens by Mr Stuart. Several have been occasionally met with at Tarentum. It would appear, however, that there were some still smaller, and of value only three fourths of a farthing. None of these have been met with; and the smallness of the size renders it improbable that any will ever be met with, as the peasants, who commonly discover coins, would probably either not observe them at all, or, if they did, would neglect them as things of no value. Medals.

Many different names have been imposed on the coins belonging to the different states of Greece. Thus κορη, *the maiden*, was a name often applied to the tetradrachm, and which would seem to apply to those of Athens; though there are coins of other cities with the head of Proserpine, and the word κορη, to which it would appear more applicable in our author's opinion. Χελωνη, *the shell*, was the name of another coin, from its type. A Sicilian coin was named δημαρετιον, from Gelon's wife. A tetradrachm was named χραπαταγους, and had eight ἑνθειας or hemidrachms. The Τροιζηνιον, so called from its country Troizene, had Pallas on one side and a trident on the reverse. The hemiobolion was the πελανος of Lacedæmon; and the κολλυβος is supposed to have been equal to the Roman sestertius or quarter drachma. The *cystophori* were coins with the mystic chest or hamper of Bacchus upon them, out of which a serpent rises; they were much celebrated in antiquity. We are told by Livy, that Marcus Acilius, in his triumph over Antiochus and the Ætolians, carried off 248,000 of them; that Cneius Manlius Vulso, in that over Gallo-Græcia, had 250,000; and that Lucius Emilius Regillus, in his naval triumph over the fleets of Antiochus, had 131,300. Cicero likewise mentions his being possessed of a vast sum in them. The most probable opinion concerning them seems to be, that they were all silver tetradrachms, such as belonged to the cities of Apamea and Laodicea in Phrygia, Pergamus in Mysia, Sardis and Tralles in Lydia, and Ephesus; but it is a mistake to ascribe any to Crete. Mr Pinkerton thinks it absurd to imagine that Crete, a small island, should strike such vast numbers of coins, though Cicero mentions his being in possession of an immense treasure in them at the time when he was governor of Asia Minor. "It is most likely," says Mr Pinkerton, "that his wealth should be in the coin of the country to which he belonged. What had these triumphs of Cicero's government to do with Cretan money? But indeed the coins themselves, as above noticed, establish the fact."

Another set of coins famous in antiquity were those of Cyzicus in Mysia, which were of gold; but they have now almost entirely vanished, by being recoined in other forms. The Αριανδικον νομισμα, or *money of Aryandes*, who was made governor of Egypt by Cambyses, is mentioned by Hesychius; but none of them, as far as is known, have reached our times. They must have been marked with Persian characters, if with any. The coin of Queen Philistis is mentioned by the same writer, and many of these pieces are still extant; but we know not where this queen reigned, nor does there seem to be any method of finding it out. Mr Pinkerton inclines to believe that she presided over Sicily; and, as a confirmation of that supposition, mentions some inscriptions of ΒΑΣΙΛΙΣΣΑΣ ΦΙΛΙΣΤΙΔΟΣ on the *gradini* of the theatre at Syracuse, but which appear not older than the Roman times. Some authors are of opinion that she reigned in Cossara or Malta, and this is considered as much more improbable.

The most particular attention with regard to the names and standard of coins is due to those of Athens, and it is remarkable that most of them which have reached us are of a very late period, with the names of magistrates inscribed upon them. Some of these bear the name of Mithridates, and few are older than the era of that prince, who, it is well known, took the city of Athens in his war with the Romans. "I suspect," says Mr Pinkerton, "that

Medals. no Athenian coins of silver are posterior to Sylla's infamous destruction of that city; an event the more remarkable, as Sallust tell us that Sylla was learned in Greek." Indeed Caligula, Nero, and most of the pests of society, were learned men, in spite of a well-known axiom of Ovid. It is still more remarkable that the fabric of Athenian coins is almost universally very rude; a singular circumstance, if we reflect how much the arts flourished there. It can only be accounted for from the excellence of their artists being such as to occasion all the good ones to be called into other countries, and none but the bad left at home. In like manner, the coins struck at Rome in the imperial times are excellent, as being done by the best Greek artists; whilst those of Greece, though famous at that time for producing unrivalled artists, are during that period commonly of very mean execution. The opulence of Athens in her days of glory was very great, owing in an eminent degree to her rich commerce with the kingdoms on the Euxine Sea, carried on chiefly from Delos, which belonged to Athens, and was the grand centre of that trade. Hence it has become matter of surprise to Neumann, that when there are so many coins of Mycene, an island even proverbially poor, there should be none of Delos. But Mr Pinkerton accounts for this from Mycene being a free state, and Delos subject to Athens. "It may be well supposed," says he, "that Athens had a mint at Delos; and such Athenian coins as have symbols of Apollo, Diana, or Latona, were struck in this island."

The copper money of the Greeks is next in antiquity to the silver. Mr Pinkerton is of opinion that it was not used at Athens till the 26th year of the Peloponnesian war; about 404 years before Christ, and 300 after silver was first coined there. The first copper coins were those of Gelo of Syracuse, about 490 B. C. The chalcos of brass, of which eight went to the silver obolus, seems to have been the first kind of Greek coin. At first it was looked upon as of so little consequence, that it became proverbial; and to say that a thing was not worth a *chalcos*, was equivalent to saying that it was worth nothing. As the Greeks became poor, however, even this diminutive coin was subdivided into two, four, nay eight λεπτα or small coins; but Pinkerton censures very severely those who have given an account of those divisions. "Pollux, and Suidas copying from him," says he, "tell us that there were seven lepta to one chalcos; a number the most unlikely that can be, from its indivisibility and incapacity of proportion. Pollux lived in the time of Commodus, so was too late to be of the smallest authority; Suidas is four or five centuries later, and out of the question. Pliny tells us that there were ten chalci to the obolus, Diodorus and Cleopatra that there were six, Isidorus says there were four; and if such writers differ about the larger denomination, we may well imagine that the smaller equally varied in different states; an idea supported by these undeniable witnesses, the coins which remain. Most of the Greek copper coin which has reached our times consists of chalci, the lepta being so small as to be much more liable to be lost." In Dr Hunter's cabinet, however, there are several of the dilepta of Athens, and, from being stamped with the representation of two owls, seem to be the same with the silver diobolus; "a circumstance," says Mr Pinkerton, "of itself sufficient to confute Pollux; for a dilepton can form no part of seven, a number indeed which never appeared in any coinage of the same metals, and is contradictory to common sense. It may be observed, that the whole brass coins of Athens published by Dr Combe are reducible to four sizes, which may be the *lepton*, *dilepton*, *tetralepton* or *hemichalcos*, and *chalcos*. The first is not above the size of one of King James I.'s farthing tokens, the last about that of our common farthing." The lepta was also called κερμα, as being change for the poor. The κιδαφος, perhaps so called from the figure of a wolf upon it, was the coin of a particular state, and, if of brass, must have weighed three chalci. The other names of the copper coins of Greece are but little known. Lycurgus ordered iron money to be coined at Sparta; but so perishable is this metal that none of that kind of money has reached our times. Medals.

After the conquest of Greece by the Romans, most of the coins of that country diminished very much in their value, the gold coinage being totally discontinued, though some of the barbarous kings who used the Greek character were permitted to coin gold; but they used the Roman model; and the standard used by the few cities in Asia who spoke the Greek language in the times of the emperors is entirely unknown. Copper seems to have been the only metal coined at that time by the Greeks themselves; and that was done upon the Roman standard, then universal through the empire, that there might be no impediment to the circulation of currency. They retained, however, some of their own terms, using them along with those of the Romans. The *assarion* or *assarium* of Rome, the name of the diminished *as*, being sixteen to the drachma or denarius, the obolus was so much diminished in value as to be struck in brass not much larger than the old chalcos, and valued at between two and three assaria, which was indeed its ancient rate as to the drachma. This appears from the copper coins of Chios, which have their names marked upon them. The brass obolus, at first equal in size to the Roman sestertius or large brass, lessens by degrees to about the size of a silver drachma. From the badness of the imperial coinage in Greece, also, it appears that brass was very scarce in that country, as well as in all the cities using the Greek characters, being found mostly in the western countries of the Roman empire. The time of this declension in size of the Greek coins is by Mr Pinkerton supposed to have been from Augustus down to Gallienus. He is of opinion, however, that the copper obolus, at first above the size of large brass, was used in Greece about the time of its first subjection to Rome; and that the lepta ceasing, the chalci came in their stead, with the dichalcus and the hemiobolion of brass.

With respect to the gold coins of the Greeks, Mr Pinkerton is of opinion that none of that metal were coined before the time of Philip of Macedon, as none have reached our times prior to the reign of that monarch. From a passage in Thucydides, our author concludes that, in the beginning of the Peloponnesian war, the Athenians had no gold coin. Speaking of the treasure in the Acropolis or citadel of Athens, at the commencement of that war, the historian mentions silver coin, and gold and silver in bullion; and had any of the gold been in coin, he would certainly have mentioned it. Philip began his reign about sixty-eight years after the beginning of the Peloponnesian war; and we can scarcely suppose that any city would have preceded the elegant and wealthy Athens in coining gold.

Notwithstanding, however, this deficiency of gold coin amongst the Greeks, it is certain that the coinage of gold had taken place in Sicily long before; as we have gold coins of Gelo about 491 B. C., of Hiero I. 478, and of Dionysius I. in 404, all using the Greek characters, though not to be ranked amongst the gold coins of Greece, as Philip caused his to be. Gold coins of Syracuse even appear of the third class of antiquity, or with an indented square, and a small figure in one of its segments. Gold coins were used in the cities of Brettium, Tarentum, and throughout Magna Græcia; also in Panticapæa in Thrace, and likewise Cosa in that country; but not in Tuscany, as is commonly believed, though Neumann proves that they were struck by Brutus, and are unquestionably as ancient as the Greek coins. The Thebans and Athenians probably coined the first gold after Philip had set them the example, and when they were attempting to resist the pro-

Medals. jects of that enterprising monarch. The Ætolians probably coined their gold during the time of their greatest power, about a century after Philip, and when they were combating the power of Aratus and the Achæan league. There is only one ἡμιχρυσος of Thebes, much worn, in Dr Hunter's cabinet, and weighing fifty-nine grains; and perhaps not above two or three χρυσοι or gold didrachms of Athens in the world, one of which is also in the collection of Dr Hunter, and weighs 132½ grains. It appears to be more modern than the reign of Philip. That monarch having got possession of the mines of Philippi in Thrace, improved them so much that they produced him annually above a thousand talents of gold, or L.2,880,000 of our money. From this gold were struck the first coins, named from the monarch, *Philippi*. They were marked with his portrait, and for many ages afterwards were so numerous that they were common in the Roman empire; whence the name *Philippi* became at length common to gold, silver, and at last even to brass coins of their size. In the time of Philip, gold was very scarce in Greece; but after the Phocians had plundered the temple of Delphi, this precious metal, which had been valued as gems, and consecrated only to the decoration of the temples of the gods, began to be known amongst the Greeks. The comparative value of gold and silver, however, seems to have been at that time very different from what it is now. Herodotus values gold at thirteen times its weight in silver; Plato, in his Hipparchus, at twelve; and even the low value of ten to one seems to have been the stated estimation in Greece, though in Rome the plenty of silver from the Spanish mines made the value of gold to be much higher; and there is no reason to think that it was ever valued in that city at less than twelve times its weight in silver. The *Philippus*, χρυσος, gold piece, or *stater*, is a didrachm, and is the most common of all the ancient coins. Mr Pinkerton is of opinion that it went for twenty silver drachms on its first appearance, but in later times for twenty-five Greek drachmæ or Roman denarii. There are proofs of the Philippi being didrachms, both from the writings of ancient authors and from numbers of the coins themselves, which remain to this day; and that the χρυσος, or principal gold coin of Greece, was of the same weight, is also evident from ancient writings. It was anciently worth about 15s.; but, valuing gold now at the medium price of L.4 per ounce, it is worth about 20s. The ἡμιχρυσος, or half the former coin, scarcely occurs of the coinage of Philip and Alexander, though it does of Hiero I. of Syracuse and of King Pyrrhus. It passed for ten silver drachmas, and was valued only at 7s. 6d. though now worth 10s. Another division of this kind might be worth about 5s. There were besides some lesser divisions of gold coins, which could not be worth above two drachmas. These were coined in Cyrene; and there were besides several old gold coins of Asia Minor, the value of which is now unknown. Mr Pinkerton supposes that they were coined not with relation to their weight as parts of the drachma, but merely to make them correspond with as many silver pieces as were necessary. There are also larger coins than the χρυσος, the διχρυσος of Alexander and Lysimachus being double its value. Some others are met with of Lysimachus, Antiochus III. and some of the Egyptian monarchs, weighing four times the χρυσος, and now worth about L.4 sterling. Some weigh even more; but this is supposed to be owing to a difference in the purity of the gold.

In Rome, as well as in Greece, the money was at first estimated by weight; and the first metal coined by that people was copper, silver being long unknown in Rome; nor is it certainly known that any silver has ever been found in the Italian mines. In Rome the first valuation of money was by the *libra gravis æris*, or pound of heavy brass; and in the progress of their conquests, the little silver and gold that came in their way was regulated by the same standard, as appears from the story of Brennus. The weights made use of were the same with those which continue to this day. The pound consisted of twelve ounces, of 458 grains each; but the pound by which the money was weighed appears to have consisted only of 420 grains to the ounce, or to have contained in all 5040 grains. This became the standard of copper; and when silver came to be coined, seven denarii went to the ounce, as eight drachms did in Greece. Gold was regulated by the *scriptulum* or *scrupulum*, the third part of a denarius, and by the larger weights just mentioned. The number ten was at first used by the Romans in counting their money; but finding afterwards that a smaller number was more convenient, they divided it into quarters; and as the quarter of ten is two and a half, they for this reason bestowed upon it the name of *sestertius*, or "half the third," to express that it was two of any weights, measures, &c. and half a third; whence the sestertius came at last to be the grand estimate of Roman money. The *as* being at first the largest, and indeed the only Roman coin, the word *sestertius* means *sestertius as*, or "two asses and a half." On the first coining of silver, the denarius of ten asses was struck in the most common and convenient denary division of money, or that by tens, the sestertius being of course two asses and a half. But the denarius being afterwards estimated at sixteen asses, the name sestertius was still applied to a quarter of the denarius, though it now contained four asses. The term *sestertius* was applied to all sums not exceeding 1000 sestertii, or L.8. 6s. 8d.; but for greater sums the mode of the sestertius was likewise altered, though not to exclude the former. Very large sums of money were estimated by the hundredweight of brass; for the Romans were at first unacquainted with the talent. The hundredweight, by way of eminence, was distinguished by the name of *pondus*, and *sestertium pondus* became a phrase for two hundredweight and a half. Mr Pinkerton is of opinion that we may value the *as libralis* of ancient Rome at about eightpence English. Estimating the *as*, therefore, at a pound weight, the *sestertium pondus* was equal to one thousand *sestertii*, or L.8. 6s. 8d.; and by a coincidence, which our author supposes to have been the effect of design, as soon as the silver coinage appeared, the *sestertium centum denariorum* was always equal to L.8. 6s. 8d. also. The word *sestertium* itself, however, seems to have been unknown prior to the coinage of silver money at Rome; the *pondera gravis æris* being sufficient before that time for all the purposes of a state in which money was so scarce. But, however this may be, the *pondus* or hundredweight of brass was precisely worth a hundred denarii, or a pound of silver. As the great sestertium was always valued at a thousand of the smaller, or L.8. 6s. 8d., we never find one sestertium mentioned in authors, but two, three, or more; ten thousand of them being equal to L.83,333. 6s. 8d. Medals.

The states from which the Romans may be supposed first to have derived their coinage were the Etruscans and the Greek colonies in Magna Græcia and Sicily. Joseph Scaliger, Gronovius, and others, contend that it was from the Sicilians that the Romans first derived their knowledge of money; but Mr Pinkerton argues that it was from the Etruscans. In confirmation of his opinion, he appeals to the state of the Roman territories in the time of Servius Tullius, who is looked upon as having been the first who coined money at Rome. At that time the whole Roman dominion did not extend beyond ten miles round the city, and was entirely surrounded by the Etruscan and Latin states; Cumæ, the next Greek colony which was of any consequence, being situated in the neighbourhood of Naples, at about the distance of 150 miles. Mr Pinkerton asks if it is reasonable to think that the Romans

Medals. received the use of money from the Etruscans and Latins, who were their neighbours, or from the Greeks, who were at a distance, and at that time, as far as appears from their history, absolutely unknown to them. "If this argument, "adds he," is strong with regard to the nearest Grecian colonies, what must it be with respect to Sicily, an island 300 miles distant from Rome, where it was not known, at that time, if a boat went by land or water?" Arguments, however, for this opinion have been derived from the similarity between the Sicilian and Roman coins, which Mr Pinkerton next proceeds to examine. The Greek pound in Sicily was called λιτρα, and consisted, like the Roman, of twelve ὐυγκιαι or ounces; and Mr Pinkerton grants that the Roman *libra* was derived from the Greek λιτρα, but denies that the *as*, or libra, a coin, was from a Sicilian model. The Sicilians had indeed a coin named λιτρα, but it was of silver, and of equal value to the Æginean standard, ten of which went to the Sicilian δεκαλιτρα. He differs from Gronovius, that the standard of Ægina was used at Corinth, and of course at Syracuse; and it appears from Aristotle, that the Sicilians had a talent or standard of their own. The Sicilian obolus or λιτρα contained also twelve ounces or *chalci*, so named at first because they weighed an ounce weight; but the ὐυγκιαι of Hiero weighed more than a troy ounce; and the brass coins of Agrigentum are marked with ciphers as far as six, the largest weighing only 186 grains, or about one third of the primitive ounce. Pinkerton denies that even the Roman denarius took its rise from the Sicilian δεκαλιτρον, as many authors assert. Were this the case, it would have weighed 180 grains; whereas the Roman denarii are not above the third part of the quantity.

From all these considerations, Mr Pinkerton is of opinion that the Sicilians borrowed the division of their λιτρα from the Etruscans, or possibly from the Romans themselves; which, he seems to think, is more probable than that the Romans had it from Sicily. The strongest argument, however, against the Roman coinage being borrowed from the Sicilian is, that though great numbers of Sicilian coins are to be found in the cabinets of medallists, yet none of them resembles in any degree the *as libralis* of the Romans. In most cabinets also there are Etruscan coins upon the exact scale of the *as libralis*, and several of its divisions; whence Mr Pinkerton has concluded, that "these, and these alone, must have afforded a pattern to the primitive Roman coinage." The Etruscans were a colony from Lydia, to which country Herodotus ascribes the first invention of coinage. "Those colonists," says Mr Pinkerton, "upon looking round their settlements, and finding that *no* silver was to be had, and *much less* gold," supplied the mercantile medium with copper; to which the case of Sweden is very similar, which, as late as the last century, had copper coins of such magnitude that wheelbarrows were used to carry off a sum not very considerable."

Some coins are found which exceed the *as libralis* in weight, and these are supposed to be prior to the time of Servius Tullius. Some of them are met with of thirty-four and fifty-three Roman ounces, having upon one side the figure of a bull rudely impressed, and upon the other the bones of a fish. They are most commonly found at Tudder, or Tudertum, in Umbria; but they appear always broken at one end, and hence Mr Pinkerton is of opinion that perhaps some might have been struck of the decussis form, or weighing ten pounds. These pieces would seem to make it evident, that the Romans derived their large brass coins from the Etruscans and neighbouring states; they are all cast in moulds, and the greater part of them appear much more ancient than the Roman asses, even such as are of the greatest antiquity.

Mr Pinkerton agrees with Sir Isaac Newton as to the time that Servius Tullius reigned in Rome, which he supposes to be about 460 before Christ. His coinage seems to have been confined to the as, or piece of brass having the impression of Janus on the one side and the prow of a ship on the other, because Janus arrived in Italy by sea. Varro, however, informs us, that the very first coins of Tullius had the figure of a bull or other cattle upon them, like the Etruscan coins, of which they were imitations. Those with the figure of Janus and the prow of a ship upon them may be supposed to have first appeared about 400 before Christ; but in a short time various subdivisions of the as were coined. The *semis*, or half, is commonly stamped with the head of Jupiter laureated; the *triens*, or third, having four ciphers, as being originally of four ounces weight, has the head of Minerva; the *quadrans*, or quarter, marked with three ciphers, has the head of Hercules wrapt in the lion's skin; the *sextans*, or sixth, having only two ciphers, is marked with the head of Mercury, with a cap and wings; whilst the *uncia*, having only one cipher, is marked with the head of Rome. All these coins appear to have been cast in moulds, by a considerable number at a time; and in the British Museum there are four of them all united together as taken out of the mould, in which perhaps dozens were cast together. In process of time, however, the smaller divisions were struck instead of being cast; but the larger still continued to be cast until the as fell to two ounces. Even after this time it was still called *libra*, and accounted a pound of copper, though there were now larger denominations of it coined, such as the *bissas* or double as; *tressis* and *quadrussis*, of three and four asses; nay, as far as *decussis* or ten asses, marked X. Olivieri mentions one in his own cabinet weighing upwards of twenty-five ounces, and cast when the as was about three ounces weight. There is likewise in the *Museum Etruscum* a decussis of forty Roman ounces, cast when the as was at four ounces. There was likewise a curious decussis in the Jesuits' Library at Rome, for which an English medallist offered L.20, but it was seized by the Pope, along with every other thing belonging to the society.

Mr Pinkerton contests the opinion of Pliny, that the as continued of a pound weight till the end of the first Punic war. This opinion, he says, is confuted by the coins which still remain, and it appears probable to him that the as decreased gradually in weight; and from one or two of the pieces which still exist, he seems to think that the decrease was slow, as from a pound to eleven ounces, then to ten, nine, &c.; but neither the as nor its parts were ever correctly sized. During the time of the second Punic war, when the Romans were sorely pressed by Hannibal, the as was reduced to a single ounce. This is said to have taken place in the 215th year before our era, being about thirty-six years after the former change. The *as libralis*, with the faces of Janus upon it, is the form most commonly met with previously to its being reduced to two ounces. Mr Pinkerton supposes that the *as libralis* continued for at least a century and a half after this coinage of Tullius, down to 300 before Christ, about the year of Rome 452, between which and the 502d year of Rome a gradual diminution of the as to two ounces must have taken place. The following table of the dates of the Roman coinage is given by Mr Pinkerton. The *as libralis*, coined by Tullius, with the figures of oxen, &c. about 167 years after the building of Rome, according to Sir Isaac Newton, or about the year before Christ 460
As libralis with Janus and the prow of a ship 400
As of ten ounces 300
Eight 290
Six 280
Four 270
Three 260
Two, according to Pliny 250
One, according to the same author 214

Medals. About 175 before Christ, also, we are informed by Pliny that the as was, by the Papyrian law, reduced to half an ounce, at which it continued till the time of Pliny himself, and long after.

After the Romans began to maintain an intercourse with Greece, a variety of elegant figures appear upon the parts of the as, though not on the as itself till after the time of Sylla. Towards the latter end of the republic, also, *dupondii*, or double asses, were coined, together with the *sestertii ærei*, which came in place of the *quadrusses*, when the denarius began to be reckoned at sixteen asses, probably at the time the latter was reduced to half an ounce. In some instances, it is to be observed that the Romans accommodated their coins to the country where their army was stationed; whence we have many coins marked as Roman, which had been coined in Magna Græcia and Sicily, and are evidently upon the Greek and not the Roman scale. In the latter part of the republican times, also, the types begin to vary; so that we have a brass coin supposed to be struck by Sextus Pompeius in Sicily, having upon it a double head of that warrior, representing a Janus. Mr Pinkerton supposes it to have been a dupondius, which indeed appears to be the case, from the double head. This coin is of copper, and still weighs an ounce, notwithstanding its antiquity.

The largest imperial copper coin was the sestertius, a piece worth about twopence of our money. Mr Pinkerton censures severely the opinion of other medallists, all of whom allege that the sestertius was of silver. "In fact," says he, "it would be as rational in any antiquary, a thousand years hence, to contend that the halfpenny and farthing are of silver, because they were so in the reign of Henry VIII." In confirmation of his own opinion, he quotes the following passage from Pliny: "The greatest glory of brass is now due to the Marian, called also that of Cordova. This, after the Livian, most absorbs the lapis calaminaris, and imitates the goodness of native orichalcum in our sestertii and dupondiarii, the asses being contented with their own copper." Gronovius confessed that he did not know what to make of this passage, and that it caused him to hesitate in his opinion. The *Livian* mine here mentioned by Pliny is supposed to have got its name from *Livia*, the wife of Augustus; and it is probable that the pieces marked with her portraits, entitled *Justitia*, *Salus*, *Virtus*, were dupondii from this very mine, the metal being exceedingly fine, and of the kind named *Corinthian brass* by the ancient medallists. Perhaps the mine received its name from the circumstance of her coins being struck in the metal obtained from it.

No change took place in the Roman coinage, from the time that the as fell to half an ounce, to the days of Pliny; but Mr Pinkerton observes, that before the time of Julius Cæsar, yellow brass began to be used, and was always looked upon as being double the value of Cyprian or red copper. There are but few coins in large brass immediately before Julius Cæsar, or even belonging to that emperor; but from the time of Augustus downward, the large coins are all found of brass, and not one of them of copper. The largest of what are called the middle size are all of yellow brass; and the next size, which is the as, and weighs half an ounce, is universally copper. What the ancients named *orichalcum*, or what we call *brass*, was always looked upon as greatly superior in value to the *æs Cyprium*. Procopius, speaking of a statue of Justinian, tells us that brass inferior in colour to gold is almost equal in value to silver. The mines of native brass were very few in number, and were owing entirely to the singular combination of copper and lapis calaminaris in the bowels of the earth, which very seldom occurs; and the ancients were very far from being well acquainted with the method of combining these two bodies artificially, so that yellow brass was always esteemed at double the value of copper; and hence, in the ancient coinages, the brass and copper pieces were kept as distinct as those of gold and silver. Medals.

Mr Pinkerton lays claim to the discovery that the imperial sestertius was of brass, and is at considerable pains to bring proofs of it. Besides the testimony of Pliny, which of itself would be decisive, this is supported by the strongest collateral evidence of other authors. From a passage in Julius Africanus, who wrote the Ἰατρικα, or *Treatise on Medicine*, it appears that the nummus, or sestertius, weighed an ounce, and of consequence that it could not be silver, but brass; and all the large imperial Roman coins weigh an ounce. We know not the age in which Julius Africanus lived; and as he makes the denarius to contain sixteen asses, he must have been before the age of Gallienus, when it had sixty. Gronovius supposes him to have been the same mentioned by Eusebius. This author speaks of a Julius Africanus who lived in the time of Heliogabalus, and whom Mr Pinkerton supposes to have been the same with the person above mentioned.

The sestertius underwent no change till the time of Alexander Severus, when it was diminished by one third of its weight. Trajanus Decius was the first who coined double sestertii, or quinarii, of brass; but from the time of Trebonianus Gallus to that of Gallienus, when the first brass ceases, the sestertius does not weigh above the third part of an ounce. The larger coins are accounted double sestertii; and after the time of Gallienus it totally vanishes. In the times of Valerian and Gallienus we find a new kind of coinage, mentioned by the name of *denarii æris*, or *Philippi ærei*. Two sizes of denarii began to be used in the time of Caracalla; the larger of six sestertii, or twenty-four assaria; the smaller of four sestertii, or sixteen assaria, as usual. In the time of Pupienus, the latter was reduced to such a small size as not to weigh more than thirty-six grains, though in Caracalla's time it weighed fifty-six. After the time of Gordian III. the smaller coin fell into disuse, as breeding confusion. The larger denarius, of six sestertii, though diminished at last to the size of the early denarius, still retained its value of six sestertii, or twenty-four assaria. The *Philippus æreus* came at length in place of the sestertius. It was also called *denarius*, from which we may learn not only their size, but that they were in value ten assaria, as the first denarius. In the reign of Diocletian, the place of the sestertius was supplied by the *follis*, that emperor having restored the silver coin to its purity, and likewise given this form to the copper; but it would seem that this restoration of the coinage only took place towards the end of his reign; for which reason we have but few of his silver coins, and still fewer of the *follis*, though the *denarii ærei* continue quite common down to the time of Constantine. The follis of Diocletian seems to have weighed above half an ounce; and Mr Pinkerton is of opinion that Diocletian designed this coin to supply the place of the denarius æreus, which of course was worth ten assaria, and six of them went to the silver denarius. From this time the assarium diminishes to the size of thirty grains; and soon after the follis appeared, the denarius æreus was entirely dropped, the former having gradually supplied its place. Some mints appear to have retained the use of the denarius longer than others; and in several the change was preceded, and gradually brought in, by washing the follis with silver or tin, as the denarius had formerly been. Pieces of this kind occur in the times of Diocletian, Maximian I. and II. and Constantius I.; that is, for about ten years after the follis made its appearance. Some countries, however, retained the denarius æreus, others the follis, and some had a medium between the two, or the follis washed in imitation of the denarius.

Towards the end of the reign of Constantine I. a new coinage was introduced throughout the whole empire. The

Medals. follis coined by this prince was of half an ounce weight; twenty-four of them going to the milliarensis, or larger silver coin. The word *follis* signifies also a purse, in which sense we sometimes find it mentioned in the Byzantine history. The common follis of silver, when it occurs by itself, means a purse of 250 milliarensis, as the sestertium was 250 denarii; and by a law of Constantine I. every man paid to the state a follis or purse according to his income. The method of counting by purses continues in Turkey to this day.

The *dupondius* was only half the value of the sestertius, or about one penny sterling; and before the yellow brass appeared it seems to have been struck upon copper, and double the size of the as. There are some of this coin, struck in the time of Julius Cæsar, in yellow brass, weighing half an ounce, with a head of Venus Victrix upon one side; on the reverse, a female figure, with serpents at her feet; whilst others have a Victory on the reverse, with Q. Oppius Pr. After the time of Augustus, the dupondius was struck in yellow brass; which Pliny tells us was also the case in his time. The word dupondiarius seems to have been used by Pliny, and adopted, not to express that the coin was *dupondius*, but that it was of dupondiary value. Neither was the former word confined to signify double weight, but was used also for double length or measure, as in the instance of *dupondius pes*, or two feet, &c. In the imperial times, therefore, *dupondius* was used, not to signify a coin of double the weight of the as, but of double the value. It was one of the most ordinary of the Roman coins, and seems to have been very common even in Constantinople. In the time of Justinian, it appears there was a custom of nicknaming young students of the law *dupondii*, against which the emperor made a law; but it is not known what gave rise to the name. The dupondius, though of the same size with the as, is commonly of finer workmanship, the metal being greatly superior in value. It continues to be of yellow brass, as well as the sestertius, till the time of Gallienus; but the as is always in copper.

The imperial as, or *assarium*, was worth only a halfpenny. At first it weighed half an ounce, and was always of copper till the time of Gallienus, when it was made of brass, and weighed only the eighth part of an ounce. From the time of Gallienus to that of Diocletian, it continued to diminish still more, the size being then twenty to an ounce. This was the same with the lepta, or smallest coins except the νουμια, which weighed only ten grains.

The parts of the as occur but seldom, which may indeed be expected, considering the low value of it; though there still occur some of those called semis, triens, quadrans, sextans, and uncia, coined in the times of Nero and Domitian. There is no small brass from the time of Pertinax to that of Gallienus, excepting that of Trajanus Decius; but in the time of Gallienus it becomes extremely common, and the coins of small brass, as well as the larger, are always marked S. C., such as want it being universally accounted forgeries; they were plated with silver, though the plating be now worn off. The small pieces struck for slaves during the time of the saturnalia, must also be distinguished from the parts of the as. The S. C. upon these most probably signifies *Saturni Consulto*, and were struck in ridicule of the true coins, as the slaves on that occasion had every privilege of irony.

The sestertius diminishes from Pertinax to Gallienus so fast that no parts of the as are struck, itself being so small. Trajanus Decius, indeed, coined some small pieces, which went for the semis of the time. The small brass coins under Gallienus were called assaria, sixty of which went to the silver denarius. They are about the size of the denarius, and some of them occur of the coinage of Gallus and his family, of half that size, which appear to have been struck during the latter part of his reign, when the assarium was diminished to a still smaller size. It is probable, however, that some of these very small coins had been struck in all ages of the empire, in order to scatter amongst the people on solemn occasions. Mr Pinkerton is of opinion that they are the *missilia*, though most other medallists think that they are medallions. "But if so," says he, "they were certainly called *missilia a non mittendo*; for it would be odd if fine medallions were scattered among the mob. It is a common custom just now to strike counters to scatter among the populace on such occasions, while medals are given to peers of the kingdom; and we may very justly reason from analogy on this occasion." Medals.

The *assarion* or *lepton* of the Constantinopolitan empire was, as we have already observed, one of the smallest coins known in antiquity, weighing no more than twenty grains; and the *noumia* were the very smallest which have reached our times, being only one half of the former. By reason of their extreme smallness, they are very scarce; but Mr Pinkerton had in his possession a fine one of Theodosius II. which had on it the emperor's head in profile: Theodosius P. F. AV.; on the reverse a wreath, having in the centre VOT. XX.: MULT. XXX.

The principal coin of the lower empire was the follis, which was divided into an half and quarter, named ἡμισοφολεος and τεταρτον; the latter of which is shown by Du Cange to have been a small brass coin, as the other is supposed to have been by Mr Pinkerton. Besides these, the follis was divided into eight oboli, sixteen assaria or lepta, and thirty-two noumia, though in common computation it contained forty of these last. This coin, notwithstanding so many divisions, was of no more value than a halfpenny.

Mr Pinkerton controverts an opinion, common amongst medallists, that the largest brass coin or follis of the lower empire had forty small coins, expressed by the letter M upon it; that the next had thirty, expressed by the letter A; that the half was marked by the letter K, and the quarter by I, which contained only ten. Mr Pinkerton informs us that he had three coins of Anastasius, all marked M in large; one of them weighed more than half an ounce; the second forty grains less; and the third of 160 grains, or one third of an ounce; but the size was so very unequal, that the last, which was very thick, did not appear above half the size of the first. There are pieces of Justinian which weigh a whole ounce; but the size of copper was increased as the silver became scarcer, and the value of the coinage cannot be deduced from the weight of the coins, as it is plain that our own coinage is not of half the value with regard to the metal. A great number of medallions were struck by Constantius II.; but there is no other copper larger than the half ounce, excepting that of Anastasius, when the follis began to be struck larger. All medallists allow the others to be medallions.

The metal employed in these very small coins, though at first of brass, was always of a base and refuse kind; but copper is generally made use of in the parts of the as from the earliest times to the latest; and if brass be sometimes employed, it is never such as appears in the sestertii and dupondiarii, which is very fine and beautiful, but only the refuse. "Yellow brass of the right sort," says Pinkerton, "seems totally to have ceased in the Roman coinage with the sestertius, under Gallienus, though a few small coins of very bad metal appear under that hue as late as Julian II."

Silver was coined in Rome only as late as the 485th year of the city, or 266 before Christ. Varro indeed speaks of silver having been coined by Servius Tullius, and of the libella having been once in silver; but Pliny's authority must be accounted of more weight than that of this author, as he mistakes the λιτρα of Sicily for Roman coins, having been current at Rome during the time of the first Punic war. Even Pliny, according to our author, very

Medals. frequently mistakes with regard to matters much antecedent to his own time; and amongst the moderns he criticises severely Erasmus and Hume. "Erasmus," says he, "who had been in England for some time, talks of leaden money being used here." Not even a leaden token was struck in the reign of Henry VIII.; yet his authority has been followed with due deference to so great a name; for how could Erasmus, who must have seen the matter with his own eyes, assert a direct falsehood? To give a later instance in a writer of reputation, Mr Hume, in the sixth volume of his history, has these words, in treating of the reign of James I. "It appears that copper halfpence and farthings began to be coined in this reign. Tradesmen had commonly carried on their retail business by leaden tokens. The small silver penny was soon lost, and at this time was nowhere to be found." Copper halfpence and farthings were not struck till Charles II., 1672. There were small tokens for farthings struck in copper by James I., but not one for the halfpenny. The silver farthings had ceased with Edward VI., but the silver halfpence continued the sole coins till Edward II. It was by copper tokens that small business was carried on. "The silver penny was much used till the end of the reign of George I.; and, so far from being nowhere to be found, was superabundant in every reign since that period, not excepting even the reign of George III. From these instances the reader may judge how strangely writers of all ages blunder when treating of a subject of which they are entirely ignorant."

The first silver denarii coined at Rome are supposed by Pinkerton to have been those which are impressed with the ROMA; and he inclines to account those the most ancient that have a double female head on the one side, and on the reverse Jupiter in a car, with Victory holding the reins, and the word ROMA indented in a rude and singular manner. The double female head seems to denote Rome, in imitation of that of Janus upon the as. There are fifteen of these in the cabinet of Dr Hunter; one of the largest weighs ninety-eight grains and a quarter, and the rest, which seem to be of the greatest antiquity, are of various weights between that and eighty-four; the smaller and more modern weigh fifty-eight or fifty-nine grains; but Mr Pinkerton is of opinion that the large ones were of the very first Roman coinage, and struck during that interval of time between the coinage of the first silver denarius and the as of two ounces. He takes the indentation of the word ROMA to be a mark of great antiquity; such a mode being scarcely known anywhere else, excepting in Caulonia, Crotona, and other towns of Italy. All of them are allowed to have been struck at least 400 B. C. As these coins are not double denarii, they must have been struck prior to the small ones; and Neumann has given an account of one of them recoined by Trajan, in which the indentation of ROMA is carefully preserved. The first denarius was in value ten asses when the as weighed three ounces; and, allowing ninety grains at a medium for one of these large denarii, the proportion of copper to silver must have been as one to a hundred and sixty; but when the as fell to one ounce, the proportion was as one to eighty; when it fell to half an ounce, so that sixteen asses went to the denarius, the proportion was as one to sixty-four, at which it remained. Copper with us, in coinage, is to silver as one to forty, but in actual value as one to seventy-two.

At Rome the denarius was worth 8d.; the quinarius 4d.; and the sestertius, whether silver or brass, 2d. The denarius is the coin from which our penny is derived, and was the chief silver coin in Rome for 600 years. According to Celsus, seven denarii went to the Roman ounce, which in metals did not exceed 430 grains; but as all the denarii hitherto met with weigh at a medium only sixty grains, this would seem to make the Roman ounce only 420 grains; though perhaps this deficiency may be accounted for from the unavoidable waste of metal, even in the best preserved of these coins. According to this proportion, the Roman pound contained eighty-four denarii; but in tale there was a very considerable excess, for no fewer than 100 denarii went to the Roman pound. The Greek ounce appears to have been considerably larger than that of Rome, containing about 528 grains; yet notwithstanding this apparently great odds, the difference in the coins was so small that the Greek money went current in Rome, and the Roman in Greece. The denarius at first went for ten asses, and was marked X; it was afterwards raised to sixteen, which Mr Pinkerton supposes to have been about 175 years before Christ. Some are met with bearing the number XVI., nay, with every number up to CCCCLXXVI. These large numbers are supposed to have been mint-marks of some kind or other. After being raised to sixteen asses, it continued at the same value till the time of Gallienus; so that till that time we are to look upon its constituent parts to be sixteen asses or assaria, eight dupondii, four brass sestertii, and two silver quinarii. Under the Emperor Severus, however, or his successor Caracalla, denarii were struck of two sizes, one of them a third heavier than the common, and which we must of consequence suppose to have borne a third more value. This large piece obtained the name of *argentus*, and *argenteus Philippus*, or the "silver Philip;" the name of Philip having become common to almost every coin. The common denarii now began to be termed *minuti* and *argenti Philippi minutuli*, &c. to express their being smaller than the rest. Some have imagined that the large denarii were of the same value with the small, and only of worse metal; but Mr Pinkerton observes, that amongst the few which have any difference of metal, the smallest are always the worst. The first mention of the *minuti* is in the time of Alexander Severus, who reduced the price of pork from eight minuti at Rome to two and to one. The *minutus argenteus* of that age was about 40 grains; and, from the badness of the metal, was not worth above 4d. of our money. Thus, the price of meat was by this prince reduced first to 8d. and then to 4d.

According to Zozimus and other writers, the purity of the Roman coin was restored by Aurelian; but Mr Pinkerton controverts this opinion, thinking it more probable that he only made the attempt without success, or that this reformation might be entirely confined to gold, on which there is an evident change after the time of this emperor. His successor Tacitus is said to have allowed no brass to be upon any account mixed with silver; yet the few coins of this emperor are very much alloyed. We are certain, however, that the emperor Diocletian restored the silver to its ancient purity; the denarii struck in his reign being very small indeed, but of as fine silver as the most ancient coins of the empire. After Gordian III. the small denarius entirely vanished, whilst the large one was so diminished that it resembled the *minutus*, or small one of Caracalla, in size. Gallienus introduced the *denarii ærei* instead of the *sestertii*. The *argenteus*, though reduced more than one third in size, contained six denarii ærei, the old standard of sestertii. According to the writers of this period, and some time afterwards, the denarius or argenteus contained sixty assaria; whence it follows that each denarius æreus had ten, and from this it probably had its name. The assaria are of the size of the argentei already mentioned, and show the copper to have retained nearly its old proportion of value to the silver, that is, one to sixty.

A larger silver coin was introduced by Constantine I. who accommodated the new money to the pound of gold, in such a manner that a thousand of the former in tale were equal to the latter in value; so that this new piece from thence obtained the name of the *milliarensis* or "thousander." Its weight at a medium was seventy grains, or seventy to the pound of silver; but Mr Pinkerton is of

Medals. opinion that it might have contained seventy-two grains, of which two have now perished by the softness of the silver; that the pound contained seventy-two; or that two of the number might be allowed for coinage, whilst the alloy alone would pay for coining gold. The code says that sixty went to the pound, but the numbers of this are quite corrupt. The *milliarensis* was worth about a shilling sterling. The argentei or denarii, however, were still the most common currency; and having been originally rated at a hundred to the pound of silver in tale, they thence began to be denominated *centenionales*, or "hundreders." Those of Constantine I. and II., Constans, and Constantius, weigh from fifty grains down to forty; those of Julian and Jovian from forty to thirty; and those of the succeeding emperors from that time to Justinian, from thirty to twenty. Under Heraclius they ceased entirely; and, from Justinian to their total abolition, had been brought down from fifteen to ten grains. A similar decrease of weight took place in the milliarensis, those of Constantine and Constans being above seventy grains in weight, those of Arcadius not above sixty, and the milliarensis of Justinian not above thirty grains; but, from the weight of those in Dr Hunter's cabinet, Mr Pinkerton deduces the medium to have been exactly seventy grains and eight seventeenths. These coins were also called *majorinæ*.

The smaller silver coins of Rome were, 1. The *quinarius*, at first called *victoriatus*, from the image of Victory on its reverse, which it continued to bear from first to last. Its original value was five asses, but it was afterwards raised to eight, when the value of the denarius increased to sixteen. According to Pliny, it was first coined in consequence of the *lex Clodia*, about the 525th year of Rome. Some are of opinion that it was called κερατιον under the Constantinopolitan empire, because it was worth a κερατιον of gold, 144 of which went to the ounce; but this is denied by Mr Pinkerton, because at the time that the word κερατιον first appears in history, the denarius did not weigh above thirty grains; and, consequently, as twenty-five must have gone to the gold solidus, of which there were six in the ounce, 130 denarii must have gone to the ounce of gold. He is therefore of opinion that the word κερατιον was only another name for the denarius when much reduced in size, probably owing to the great scarcity of silver in Constantinople; though in the same city there was plenty of gold, and consequently the gold solidus was never diminished; for Montesquieu has well observed, that gold must be common where silver is rare. Hence gold was the common regulation of accounts in the eastern empire. The δικεραιον met with in ancient authors was, according to Mr Pinkerton, merely an improper name for the *milliarensis*, when, on account of the scarcity of silver, the denarius was reduced, and no milliarenses coined; so that the current milliarensis of former reigns happened to be double to the denarius or centenionalis. The quinarius diminishes in size along with the other coins; those of Augustus weighing thirty grains, those of Severus twenty-five, those of Constantine I. twenty, those of Justinian twelve, and those of Heraclius only five. A new silver coinage seems to have taken place after the days of this emperor, as the little we then meet with, which in the best cabinets scarcely exceeds a dozen of coins, consists entirely of large unshapely pieces of coarse metal.

The consular denarius had also four silver sestertii, till the as fell to half an ounce, when it was thought proper to coin the sestertius in brass, as it continued to be ever afterwards. The very last silver sestertius which appears is one with a head of Mercury, and H. S.; on the reverse a caduceus P. SEPVLLIVS, who appears to be the P. SEPVLLIVS MACER of the denarii of Julius Cæsar. If so, as is most probable, the sestertius was coined in silver down to Augustus; and it is of course not to be expected that any of brass can appear till Augustus, under whom they were in fact quite common. We have indeed seen no coin which could be a consular brass sestertius; and though we have certainly brass dupondii of Cæsar, yet it is reasonable to infer that the brass sestertius was first coined by Augustus. Not one silver sestertius appears during the whole imperial period; yet we know that the sestertius was the most common of all silver coins. The consular sestertii of silver, marked H. S. are not uncommon, nor the quinarii; but the latter are very scarce of all the emperors, if we except one instance, the ASIA RECEPTA of Augustus. Medals.

The Roman gold coinage was still later than that of silver. Pliny tells us, that "gold was coined sixty-two years after silver; and the scruple went for sixty sesterces. It was afterwards thought proper to coin forty pieces out of the pound of gold. And our princes have by degrees diminished their weight to forty-five in the pound." This account is confirmed by the pieces which still remain; for we have that very coin weighing a scruple which went for twenty sesterces. On one side is the head of Mars, and on the other an eagle; and it is marked xx. We have another coin of the same kind, but double, marked xxxx; and its triple, marked ⅄x or 60; the ⅄ being the old numeral character for 50. Mr Pinkerton, the discoverer of this, treats other medallists, as usual, with great asperity. Savot and Hardouin are mentioned by name; the latter, he says, is "ignorant of common sense;" and neither he nor Savot could explain it but by reading backwards, putting the ⅄ for the Roman V, and thus making it xv. Other readings have been given by various medallists, but none have hit upon the true one excepting our author, though the coin itself led to it, being just three times the weight of that marked xx. We have likewise half the largest coin, which is marked xxx, and which weighs twenty-six grains; the smallest is only seventeen and a half, and the xxxx weighs thirty-four, and the LX or drachma fifty-three. There is also the didrachm of this coinage, of a hundred and six grains.

The *aurei*, or Roman gold coins, were at first forty-eight in the pound; but they were afterwards diminished in number to forty, owing to an augmentation in the weight of each coin. In the time of Sylla, the aureus weighed no less than from a hundred and sixty-four to a hundred and sixty-eight grains, and there were only thirty in the pound; but such confusion in the coinage was introduced by that conqueror, that no person could know exactly what he was worth. Till this time the aureus seems to have continued of the value of thirty silver denarii, about one pound sterling; for about that time it was enlarged a whole third, that it might still be equivalent to the full number of denarii. But after Sylla had taken Athens, and the arts and manners of Greece became objects of imitation to the Romans, the aureus fell to forty in the pound, probably when Sylla had abdicated his dictatorship. Thus, being reduced near to the scale of the Greek χρυσος, it passed for twenty denarii, as the latter did for as many drachmas, being in currency 13s. 4d. sterling. "This," says Pinkerton, "is the more probable, because we know from Suetonius, that the great Cæsar brought from Gaul so much gold that it sold for nine times its weight of silver; but the Gallic gold was of a very base sort."

In the time of Claudius, the aureus was valued at a hundred sesterii, or twenty-five silver denarii, at which it continued till the time of Heliogabalus, when it fell to about ninety-two grains at a medium, or rose in number to fifty-five in the pound. In the reign of Philip, during which the city completed its thousandth year, the aureus was coined of two or three sizes. These are impressed with a head of Rome on one side, and various figures on the other; but the workmanship is so rude that they are supposed to have been struck in some of the more uncivilized provin-

Medals. ces of the empire. The practice of having different gold coins, however, continued under Valerian, Gallienus, and his successors. In the time of Gallienus, they were of thirty, sixty-five, and from eighty-six to ninety-three grains, the double aurei being from 172 to 183½ grains; but the areus properly so called was from eighty-six to ninety-three, those of thirty and thirty-two being the *trientes aurei* of the *Historiæ Augustæ Scriptores;* whilst the larger, from sixty-two to sixty-five, are to be accounted double trientes, and were perhaps called *minuti aurei.* The value of these different sizes of aurei is not known.

That Aurelian made some alteration in the coin is certain; but Pinkerton supposes it to have been only in the gold, because under him and his successor Probus the common aureus was of a hundred grains, a size confined to those emperors. There are likewise halves of about fifty grains, and double aurei, commonly of very fine workmanship, and upwards of two hundred grains. In the time of Gallienus, the precious metal was so common that this emperor vied in magnificence with Nero and Heliogabalus. Aurelian, who plundered the rich city of Palmyra, and thus became master of the treasures of the East, obtained such a profusion of gold, that he looked upon it as being produced by nature in greater plenty than silver. It is remarkable, that during this emperor's reign, there was a rebellion amongst the money coiners, that could not be quelled but by the destruction of several thousands; which Mr Pinkerton ascribes to his having ordered the gold to be restored to its former size, but to go for no more silver than it formerly did. "So very little silver," says he, "occurs of this period, that it is plain no alteration in the silver produced the war with the moneyers; and in the brass he made no change; or if he had, it were strange that such commotions should arise about so trifling a metal. But if, as appears from the coins, he ordered the aureus, which had fallen to eighty grains, to be raised to about a hundred, it is no wonder that the contractors should be in an uproar; for a whole quarter of their coinage, amounting, as would seem, to all their profits, was lost. Aurelian judged, that when he found gold so common in the East, it was equally so in the west, and that the moneyers must have made a most exorbitant profit; but his ideas on this subject were partial and unjust: and after his short reign, which did not exceed five months after the alteration, the gold returned to its former course, though a few pieces occur of Aurelian's standard, struck, as would seem, in the commencement of the reign of Probus his successor.

From this time to that of Constantine I. the aureus weighed between seventy and eighty grains; but in his reign it was changed for the solidus, of which six went to the ounce of gold, which passed for fourteen *milliarenses,* and twenty-five denarii, as before; the value of silver being now to gold as fourteen to one. This new coin continued of the same value till the final downfall of the Constantinopolitan empire, gold being always very plentiful in that city, though silver became more and more scarce. The solidus was worth 12s. sterling. Here again Mr Pinkerton severely criticises Mr Clarke and Mr Raper. The former, he says, with respect to the value of gold in the time of Constantine "has left all his senses behind him. In page 267, he absurdly asserts that twenty denarii went to the solidus in the time of Theodosius I., and proceeds with this deplorable error to the end of his work. He then tells us that only fourteen denarii went to the solidus under Constantine I." To Mr Raper, however, he is a little more merciful, owning that, "though he has strangely confounded the milliarensis with the denarius, he has yet kept common sense for his guide." Mr Pinkerton, indeed, argues with great probability, "that had any change in the coinage taken place between the time of Constantine and Theodosius I. that is, in less than fifty years, the laws of that period, which are all in the Theodosian code, must have noticed it." To this and other arguments upon the subject Mr Pinkerton adds the following observation upon the value of gold and silver: "As a state advances to its height, gold increases in value; and as a state declines, it decreases, providing the metals are kept on a par as to purity. Hence we may argue, that gold decreased in its relation to silver perhaps four or five centuries, furnished most European kingdoms with gold in coin, which otherwise would, from their want of arts and of intercourse with the East, then the grand seminary of that metal, have been almost altogether ignorant of gold. These gold coins were called Bezants in Europe, because sent from Byzantium or Constantinople, and were *solidi* of the old scale, six to the ounce. In the Byzantine writers, the solidus is also called *nomisma,* or the coin; *crysinos,* because of gold; and *hyperperos,* from its being refined with fire, or from its being of bright gold flaming like fire. The *solidi* also, as the *aurei* formerly, received names from the princes whose portraits they bore; as *Michelati, Manuelati. Solidus* is a term likewise used for the aureus by Apuleius, who lived in the time of Antoninus the Philosopher; nay, as early as the prætorian edicts of the time of Trajan. It was then a distinction from the semissis or half. In the time of Valerian, when aurei of different sizes had been introduced, it became necessary to distinguish the particular aurei meant. Hence, in the imperial rescripts published by the *Historiæ Augustæ Scriptores,* Valerian uses the term *Philippi nostri vultus* for the common aurei. Aurelian uses the same term *aurei Philippei* for the aurei, which he had restored to their size in some degree. Gallienus uses *aurei Valeriani* for his father's coins. *Aurei Antoniniani* are likewise put by Valerian for coins of the early Antonini, of superior standard to any then used.

In the first gold coinage at Rome the aureus was divided into four parts: the semissis of sixty sestertii; the tremissis or third, of forty; the fourth, the name of which is not mentioned, of thirty; and the scrupulum of twenty. But in a short time all of these fell into disuse, except the semissis or half, which is extremely scarce; so that it is probable that few have been struck. It is an erroneous opinion (according to Mr Pinkerton) that the semissis was called a *denarius aureus.* The aureus itself indeed had this name; but the name of *quinarius* is applied to the semissis with greater propriety than the former. Trientes or tremisses of gold are found of Valerian and his son Gallienus, and weigh about thirty grains. Those of Salonina, the wife of Gallienus, weigh thirty-three grains. Under the Constantinopolitan empire, tremisses again made their appearance; and from the time of Valentinian downwards, the thirds are the most common kinds of gold, being worth about 4s. sterling. The semissis is likewise mentioned, but none occurs earlier than the time of Basiliscus. The gold tremissis was the pattern of the French and Spanish gold coins; as the silver denarius, in its diminished state, was of the Gothic and Saxon penny.

We shall close this account of the Roman money with some remarks concerning the mint and method of coinage. This at first seems to have been under the direction of the quæstor. About the time that silver was first coined in Rome, viz. about 266 B. C. the *triumviri monetales* were created. They were at first of senatorial rank, but were by Augustus chosen from amongst the equestrian order; and the title of *triumviri* was continued till after the time of Caracalla; but under Aurelian there was probably but one master of the mint, called *rationalis;* and Pinkerton is of opinion that the change took place under Gallienus. He seems also to have permitted the provincial cities to coin gold and silver, as well as to have altered the form of the mints in the capital, and to have ordered them all to strike money with Latin legends, and of the same forms; as in

Medals. his time we first meet with coins with mint marks of cities and offices. The violent insurrection which took place in his reign has already been mentioned, as well as its probable cause; and Mr Gibbon has shown, that the concealed enemies of Aurelian took such advantage of this insurrection, that it cost 7000 of his best troops before it could be quelled. About this time the *procurator monetæ* seems to have succeeded the *rationalis* as director of the mint. In the colonies, the direction of the mint seems to have been given to the decemviri, whose names frequently occur in colonial coins, which, though generally of rude invention and ruder execution, are yet often interesting and important.

The engraving of the ancient dies used in coinage was a work of much genius and labour, and at Rome Greek artists were generally employed in it; but it has been thought a matter of great surprise that scarce any two ancient coins are to be found exactly the same. Hence some antiquaries have imagined that only a single coin was thrown off from each die. Beauvais informs us that the only two Roman imperial coins of the first times which he had seen perfectly alike were those of the Emperor Galba. It is, however, the opinion of the best judges, that a perfect similarity between two medals is a very great reason for supposing one of them to be forged. "It must also be observed," says Mr Pinkerton, "that the differences in coins apparently from the same die are often so minute as to escape an eye not used to microscopic observations of this sort. But it would be surprising if any two ancient coins were now found struck with the same die; for, out of each million issued, not above one has reached us. Dies soon gave way by the violence of the work, and the ancients had no puncheons or matrices, but were forced to engrave many dies for the same coin. Even in our mint, upon sending for a shilling's worth of new halfpence, it will appear that three or four dies have been used. Sometimes the obverse of the die gives way, sometimes the reverse; but among us it is renewed by puncheons, though with variations in the lettering or other minute strokes; while the ancients were forced to recur to another die differently engraven. The engravers of the die were called *cælatores;* other officers employed in the mint were the *spectatores, expectatores,* or *nummularii.* The melters were styled *fusarii, flatuarii,* and *flaturarii;* those who adjusted the weight were called *æquatores monetarum;* those who put the pieces into the die, *suppositores;* and those who struck them, *malleatores.* At the head of each office was an officer named *primicerius,* and the foreman was named *optio et exactor.*"

In order to assist the high relief on the coins, the metal, after being melted aud refined, was cast into bullets, as appears from the ancient coins not being cut or filed on the edges, but often cracked, and always rough and unequal. These bullets were then put into the die, and received the impression by repeated strokes of the hammer, though sometimes a machine appears to have been used for this purpose; for Boiterue informs us, that there was a picture of the Roman mintage in a grotto near Baiæ, where a machine was represented holding up a large stone, as if to let it fall suddenly, and strike the coin at once. None of the ancient money was cast in moulds, excepting the most ancient and very large Roman brass, commonly called *weights,* and other Italian pieces of that sort; all the rest being mere forgeries of ancient and modern times. Some Roman moulds which have been found are a proof of this; and from these certain medallists have erroneously imagined that the ancients first cast their money in moulds, and then stamped it in order to make the impression more clear and sharp.

The ancients had some knowledge of the method of crenating the edges of their coins, which they did by cutting out regular notches upon them; and of this kind we find some of the Syrian and ancient consular coins, with a few others. The former were cast in this shape, and then struck; but the latter were crenated by incision, to prevent forgery, by showing the inside of the metal. But the ancient forgers also found out a method of imitating this; for Pinkerton informs us that he had a Roman consular coin, of which the incisions, like the rest, were plated with silver over the copper. Medals.

VI.—*Of the Preservation of Medals.*

We now come to consider what it is that distinguishes one medal from another, and why some are so highly prized in comparison of others. This, in general, besides its genuineness, consists in the high degree of preservation in which it exists. This is called by Pinkerton the *conservation* of medals, and is by him regarded as *good* and as *perfect.* In this he says that a true judge is so nice, that he will reject even the rarest coins if in the least defaced either in the figures or legend. Some, however, are obliged to content themselves with those which are a little rubbed, whilst those of superior taste and abilities have in their cabinets only such as are in the very state in which they came from the mint; and such, he says, are the cabinets of Sir Robert Austin, and Horace Walpole, of Roman silver, at Strawberryhill. It is absolutely necessary, however, that a coin be in what is called *good* preservation; which in the Greek or Roman emperors, and the colonial coins, is supposed to be when the legends can be read with some difficulty; but when the conservation is perfect, and the coin just as it came from the mint, even the most common coins are valuable.

The fine rust, like varnish, which covers the surface of brass and copper coins, is found to be the best preserver of them, and is brought on by lying in a certain kind of soil. Gold cannot be contaminated but by iron mould, which happens when the coin lies in a soil impregnated with iron; but silver is susceptible of various kinds of rust, principally green and red, both of which yield to vinegar. In gold and silver coins the rust must be removed, as being prejudicial; but in brass and copper it is preservative and ornamental, a circumstance taken notice of by the ancients. "This fine rust," says Mr Pinkerton, "which is indeed a natural varnish not imitable by the art of man, is sometimes of a delicate blue, like that of a turquoise; sometimes of a bronze brown, equal to that observable in ancient statues of bronze, and so highly prized; and sometimes of an exquisite green, a little on the azure hue, which last is the most beautiful of all. It is also found of a fine purple, of olive, and of a cream colour or pale yellow; which last is exquisite, and shows the impression to as much advantage as paper of cream colour, used in all great foreign presses, does copperplates and printing. The Neapolitan patina (the rust in question) is of a light green; and, when free from excrescence or blemish, is very beautiful. Sometimes the purple patina gleams through an upper coat of another colour, with as fine effect as a variegated silk or gem. In a few instances a rust of a deeper green is found; and it is sometimes spotted with the red or bronze shade, which gives it quite the appearance of the East Indian stone called the *blood-stone.* These rusts are all, when the real product of time, as hard as the metal itself, and preserve it much better than any artificial varnish could have done; concealing at the same time not the most minute particle of the impression of the coin."

The value of medals is lowered when any of the letters of the legend are misplaced; as a suspicion of forgery is thus induced. Such is the case with many of those of Claudius Gothicus. The same, or even greater, diminution in value takes place in such coins as have not been well fixed in the die, which has occasioned their slipping

Medals. under the strokes of the hammer, and thus made a double or triple image. Many coins of this kind are found, in which the one side is perfectly well formed, but the other blundered in the manner just mentioned. Another blemish, but of smaller moment, and which to some may be rather a recommendation, is when the workmen through inattention have put another coin into the die without taking out the former. Thus the coin is convex on one side, and concave on the other, having the same figure upon both its sides.

The medals said by the judges in this science to be *countermarked* are very rare, and highly valued. They have a small stamp impressed upon them; in some a head, in others a few letters, such as AUG : N. PROBUS, &c.; which marks are supposed to imply an alteration in the value of the coin, as was the case with the countermarked coins of Henry VIII. and Queen Mary of Scotland. Some have a small hole through them; sometimes with a little ring fastened in it, having been used as ornaments; but this makes no alteration in their value. Neither is it any diminution in the value of a coin that it is split at the edges; for coins of undoubted antiquity have often been found in this state, the cause of which has been already explained. On the contrary, this cracking is generally considered as a great merit; but Mr Pinkerton suspects that one of these cracked coins has given rise to an error with respect to the wife of Carausius, who reigned for some time in Britain. The inscription is read ORIUNA AUG; and there is a crack in the medal just before the O of oriuna. Without this crack Mr Pinkerton supposes that it would have been read FORTUNA AUG.

Some particular soils have the property of giving silver a yellow colour, as if it had been gilt. It naturally acquires a black colour through time, which any sulphureous vapour will bring on in a few minutes. From its being so susceptible of injuries, it was always mixed by the ancients with much alloy, in order to harden it. Hence the impressions of the ancient silver coins remain perfect to this day, whilst those of modern coins are obliterated in a few years. On this account Pinkerton expresses a wish that modern states would allow a much greater proportion of alloy in their silver coin than they usually do. As gold admits of no rust except that from iron above mentioned, the coins of this metal are generally in perfect conservation, and fresh as from the mint.

To cleanse gold coins from this rust, it is best to steep them in aquafortis, which, though a very powerful solvent of other metals, has no effect upon gold. Silver may be cleansed by steeping for a day or two in vinegar, but more effectually by boiling in water with three parts of tartar and one of sea-salt; on both these metals, however, the rust is always in spots, and never forms an entire incrustation, as on brass or copper. The coins of these two metals must never be cleansed, as they would thus be rendered full of small holes eaten by the rust. Sometimes, however, they are found so totally obscured with rust, that nothing can be discovered upon them; in which case it is best to clear them with a graver; but it may also be done by boiling them for twenty-four hours in water with three parts of tartar and one of alum; not sea-salt, as in silver coins.

The high state of preservation in which ancient coins are usually found is thus accounted for by Mr Hancarville. He observes, that the chief reason is the custom of the ancients always to bury one or more coins with their dead, in order to pay for their passage over the river Styx. "From Phidon of Argos," says he, "to Constantine I. are thirty-six generations; and from Magna Græcia to the Euphrates, from Cyrene to the Euxine Sea, Grecian arts prevailed, and the inhabitants amounted to above 30,000,000. There died, therefore, in that time and region, not less than ten thousand millions of people, all of whom had coins of one sort or other buried with them. The tombs were sacred and untouched; and afterwards neglected, till modern curiosity or chance began to disclose them. The urn of Flavia Valentina, in Mr Towley's capital collection, contained seven brass coins of Antoninus Pius and Heliogabalus. Such are generally black, from being burnt with the dead. The best and freshest coins were used on these occasions from respect to the dead; and hence their fine conservation. At Syracuse a skeleton was found in a tomb, with a beautiful gold coin in its mouth; and innumerable other instances might be given, for hardly is a funeral urn found without coins. Other incidents also conspire to furnish us with numbers of ancient coins, though the above-recited circumstance be the chief cause of perfect conservation. In Sicily, the silver coins with the head of Proserpine were found in such numbers as to weigh 600 French livres or pounds. In the sixteenth century, 60,000 Roman coins were found at Modena, thought to be a military chest hid after the battle of Bedriacum, when Otho was defeated by Vitellius. Near Brest, in the year 1760, between 20,000 and 30,000 Roman coins were found. A treasure of gold coins of Lysimachus was found at Deva on the Marus; and Strabo (lib. vii.) and Pausanias (in *Attic.*) tell that he was defeated by the Getæ, at which time this treasure seems to have fallen into their hands.

Thus far Mr Pinkerton, proceeding on the authority of Mr Hancarville and others. But considering these vast numbers of coins found in various places, it seems surprising how so few should now remain in the cabinets of the curious, as the same author informs us that the whole of the different ancient coins known to us amount only to about 80,000, though he owns that the calculation cannot be esteemed accurate.

VII.—*How to distinguish true Medals from Counterfeits.*

The most difficult and the most important thing in the whole science of medals is the method of distinguishing the true from the counterfeit. The value put upon ancient coins made the forgery of them almost coeval with the science itself; and as no laws inflict a punishment upon such forgers, men of great genius and abilities have undertaken the trade: but whether to the real detriment of the science or not, is a matter of some doubt; for if only exact copies of genuine medals are sold for the originals, the imposition may be deemed trifling. But the case must be accounted very different, if people take it upon them to forge medals which never existed. At first the forgeries were extremely gross; and medals were forged of Priam, of Aristotle, Artemisia, Hannibal, and most of the other illustrious personages of antiquity. Most of these were done in such a manner, that the fraud could easily be discovered; but others have imposed even upon very learned men. Pinkerton mentions a remarkable medal of the Emperor Heraclius, representing him in a chariot on the reverse, with Greek and Latin inscriptions, which Joseph Scaliger and Lipsius imagined to have been struck in his own time, but which was certainly issued in Italy in the fifteenth century. "Other learned men," says he, "have been strangely misled, when speaking of coins; for to be learned in one subject excludes not gross ignorance in others. Budæus (*de Asse*) quotes a denarius of Cicero, M. TULL. Erasmus, in one of his Epistles, tells us with great gravity, that the gold coin of Brutus struck in Thrace, ΚΟΣΩΝ, bears the patriarch Noah coming out of the ark with his two sons, and takes the Roman eagle for the dove with the olive branch. Winkelman, in his letters, informs us that the small brass piece with Virgil's head, reverse EPO, is undoubtedly ancient Roman; and adds, that no

Medals. knowledge of coins can be had out of Rome; but Winkelman, so conversant in statues, knew nothing of coins. It is from other artists and other productions that any danger of deceit arises. And there is no wonder that even the skilful are misled by such artists as have used this trade; for among them appear the names of Victor Gambello, Giovani del Cavino, called the PADUAN, and his son Alessandro Bassiano, likewise of Padua, Benvenuto Cellini, Alessandro Greco, Leo Aretino, Jacobo da Frezzo, Federigo Bonzagna, and Giovani Jacopo, his brother; Sebastiano Plumbo, Valerio de Vizenza, Gorlæus, a German, Carteron of Holland, and others, all or most of them of the 16th century; and Cavino the Paduan, who is the most famous, lived in the middle of that century. The forgeries of Cavino are held in no little esteem, being of wonderful execution. His and those of Carteron are the most numerous, many of the other artists here mentioned not having forged above two or three coins. Later forgers were Dervieu of Florence, who confined himself to medallions, and Cogornier, who gave coins of the thirty tyrants in small brass. The chief part of the forgeries of Greek medals which have come to my knowledge are of the first mentioned, and a very gross kind, representing persons who could never appear upon coin, such as Priam, Æneas, Plato, Alcibiades, Artemisia, and others. The real Greek coins were very little known or valued till the works of Goltzius appeared, which were happily posterior to the era of the grand forgers. Why later forgers have seldom thought of counterfeiting them cannot be easily accounted for, if it is not owing to the masterly workmanship of the originals, which set all imitation at defiance. Forgeries, however, of most ancient coins may be met with, and of the Greek among the rest."

The forgeries are more conspicuous among the Roman medals than any other kind of coins; but we are not to look upon all these as the work of modern artists. On the contrary, we are assured that many of them were fabricated in the times of the Romans themselves, some of them being even held in more estimation than the genuine coins themselves, on account of their being plated, and otherwise executed in a manner to which modern forgers could never attain. Even the ancients held some of these counterfeits in such estimation, that Pliny informs us there were frequently many true denarii given for one false one. Caracalla is said to have coined money of copper and lead plated with silver; and plated coins, the work of ancient forgers, occur of many Greek cities and princes; nay, there are even forgeries of barbaric coins. "Some Roman coins," says Mr Pinkerton, "are found of iron or lead plated with brass, perhaps trials of the skill of the forger. Iron is the most common; but one decursio of Nero is known of lead plated with copper. Neumann justly observes, that no historic faith can be put in plated coins, and that most faulty reverses, &c. arise from plated coins not being noticed as such. Even of the Roman consular coins not very many have ever been forged. The celebrated silver denarius of Brutus, with the cap of liberty and two daggers, is the chief instance of a consular coin of which a counterfeit is known. But it is easily rejected by this mark: in the true coin the cap of liberty is below the guard or hilt of the daggers; in the false, the top of it rises above that hilt.

The imperial series of medals is the grand object of modern medallic forgeries; and the deception was at first extended to the most eminent writers upon the subject. The counterfeits are by Mr Pinkerton divided into six classes.

I. Such as are known to be imitations, but valued on account of the artists by whom they are executed. In this class the medals of the Paduan rank highest; the others being so numerous that a complete series of imperial medals of almost every kind, nay, almost of every medallion, may be formed from among them. In France, particularly, by far the greater part of the cabinets are filled with counterfeits of this kind. They are distinguished from such as are genuine by the following marks: 1. The counterfeits are almost universally thinner. 2. They are never worn or damaged. 3. The letters are modern. 4. They are either destitute of varnish entirely, or have a false one, which is easily known by its being black, shining, and greasy, and very easily hurt by the touch of a needle, while the varnish of ancient medals is as hard as the metal itself. Instead of the greasy black varnish above mentioned, indeed, they have sometimes a light green one, spotted with a kind of iron marks, and composed of sulphur, verdigris, and vinegar. It may frequently be distinguished by the hairstrokes of the pencil with which it was laid on being visible upon it. 5. The sides are either filed or too much smoothed by art, or bear the marks of a small hammer. 6. The counterfeits are always exactly circular, which is not the case with ancient medals, especially after the time of Trajan. Medals.

The Paduan forgeries may be distinguished from those of inferior artists by the following marks: 1. The former are seldom thinner than the ancient: 2. They very seldom appear as worn or damaged, but the others very frequently, especially in the reverse, and legend of the reverse, which sometimes, as in forged Othos, appear as half consumed by time: 3. The letters in moulds taken from the antique coins have the rudeness of antiquity: 4. False varnish is commonly light green or black, and shines too much or too little: 5. The sides of forged coins are frequently quite smooth, and undistinguishable from the ancient, though to accomplish this requires but little art: 6. Counterfeit medals are frequently as irregular in their form as the genuine; but the Paduan are generally circular, though false coins have often little pieces cut off, in perfect imitation of the genuine: 7. In cast coins, the letters do not go sharp down into the medal, and have no fixed outline; their minute angles, as well as those of the drapery, are commonly filled up, and have not the sharpness of the genuine kind. Where the letters or figures are faint, the coin is greatly to be suspected.

The letters form the great criterion of medals, the ancient being very rude, but the modern otherwise; the reason of which, according to Cellini, is, that the ancients engraved all their matrices with the graver or burin, while the modern forgers strike theirs with a punch.

According to Vico, the false patina is green, black, russet, brown, gray, and iron colour. The green is made from verdigris, the black is the smoke of sulphur, the gray is made of chalk steeped in urine, the coin being left for some days in the mixture. The russet is next to the natural, by reason of its being a kind of froth which the fire forces from ancient coins; but when false, it shines too much. To make it, they frequently took the large brass coins of the Ptolemies, which were often corroded, and made them red hot in the fire, put the coins upon them, and a fine patina adhered. Sometimes they took an old defaced coin, covered with real patina, and stamped it anew; but the patina is then too bright in the cavities, and too dull in the protuberances. The trial of brass coins with the tongue is not to be despised; for, if modern, the patina tastes bitter or pungent, while, if ancient, it is quite tasteless.

Mr Pinkerton informs us, that all medallions from Julius Cæsar to Adrian are much to be suspected of forgery; the true medals of the first fourteen emperors being exceedingly valuable, and to be found only in the cabinets of princes.

II. The second class of counterfeit medals contains those cast from moulds taken from the Paduan forgeries, and

Medals. others done by eminent masters. These are sometimes more difficult to be discovered than the former, because in casting them they can give any degree of thickness they please; and, filling the small sandholes with mastic, they retouch the letters with a graver, and cover the whole with varnish. The instructions already given for the former class, however, are also useful for those of the second; with this addition, that medals of this class are generally lighter than the genuine, because fire rarefies the metal in some degree, whilst that which is struck is rather condensed by the strokes. In gold and silver medals there cannot be any deception of this kind, because these metals admit not of patina, and consequently the varnish betrays the imposition. The marks of the file on the margin of those of the second class are a certain sign of forgery, though these do not always indicate the forgery to be of modern date, because the Romans often filed the edges of coins to accommodate them to the purposes of ornament, as quarter guineas are sometimes put into the bottoms of punch ladles. It is common to imitate the holes of medals made by time, by means of aquafortis; but this destroys the sides of a coin more effectually than if it had been naturally corroded. The fraud, however, is not easily distinguished.

III. *Medals cast in moulds from the antique.*—In this mode some forgers, as Beauvais informs us, have been so very careful, that they would melt a common medal of the emperor whom they meant to counterfeit, lest the quality of the metal should betray them. "This," says Pinkerton, "has been done in the silver Septimius Severus, with the reverse of a triumphal arch, for which a common coin of the same prince has been melted; and in other instances." Putting medals in the fire or upon hot iron to cleanse them, gives them an appearance of being cast; for some spots of the metal, being softer than the rest, will run, which makes this one of the worst methods of cleaning medals. The directions given for discovering the two former deceptions hold good also in this.

IV. *Ancient medals retouched and altered.*—This is a class of counterfeits more difficult to be discovered than any other. "The art," says Pinkerton, "exerted in this class is astonishing; and a connoisseur is the less apt to suspect it, because the coins themselves are in fact ancient. The acute minds of the Italian artists exerted themselves in this way when the other forgeries became common and known. With graving tools they alter the portraits, the reverses, and the inscriptions themselves, in a surprising manner. Of a Claudius struck at Antioch they make an Otho; of a Faustina, a Titiana; of a Julia Severa, a Didia Clara; of a Macrinus, a Pescennius, &c. Give them a Marcus Aurelius, he starts up a Pertinax, by thickening the beard a little, and enlarging the nose. In short, wherever there is the least resemblance in persons, reverses, or legends, an artist may from a trivial medal generate a most scarce and valuable one. This fraud is distinguishable by the false varnish which sometimes masks it; but, above all, by the letters of the legend, which are always altered. Though this be sometimes done with an artifice almost miraculous, yet most commonly the characters straggle, are disunited, and not in a line."

In counterfeits of this kind, sometimes the obverse is not touched, but the reverse made hollow, and filled with mastic coloured like the coin, and engraved with such device and legend as is most likely to bring a great price; others are only retouched in some minute parts, by which, however, the value of the coin is much diminished. Against all these arts severe scrutiny must be made by the purchaser, upon the medal itself; and the investigation and opinion of eminent antiquaries must be obtained as to its being altered, or genuine when issued from the mint.

V. *Medals impressed with new devices, or soldered.*—In the first article of this class the reverses have been totally filed off, and new ones impressed with a die and hammer. This is done by putting the face or obverse, whichever is not touched, upon different folds of pasteboard, and then applying the die and striking it with a hammer. The forgery in this class is very easily discovered, because the devices and inscriptions on the counterfeits are known not to exist on true medals; as the Pons Ælius on the reverse of Hadrian, the Expeditio Judaica of the same emperor, &c. The difference of fabrication in the face or reverse will be discovered at the first glance by any person of skill.

The soldered medals consist of two halves belonging to different medals, sawed through the middle, and then joined with solder. This mode of counterfeiting is common in silver and in brass coins. "They will take an Antoninus, for example, and saw off the reverse, then solder to the obverse, which they have treated in the same manner. This makes a medal which, from an unknowing purchaser, will bring a hundred times the price of the two coins which compose it. When the deceit is used in brass coins, they take care that the metals be of one hue, though indeed some pretenders in this way sometimes solder copper and brass together, which at once reveals the deceit. Medals which have a portrait on each side, and which are generally valuable, are the most liable to a suspicion of this fraud. To a very nice eye the minute ring of solder is always visible; and upon inserting a graver, the fabrication falls into halves."

In the same manner reverses are sometimes soldered to faces not originally belonging to them; as one mentioned by Père Jobert, of Domitian with an amphitheatre, with a reverse of Titus joined to it. Another art is sometimes made use of in this kind of counterfeits, of which there is an instance in the temple of Janus upon Nero's medals, where the middle brass is taken off, and inserted in a cavity made in the middle of a large coin of that prince. In the coins of the lower empire, however, the reverses of medals are sometimes so connected with their obverses, that a suspicion of forgery sometimes occurs without any foundation. They are met with most commonly after the time of Gallienus, when such a number of usurpers arose that it was difficult to obtain an exact portrait of their features; the coiners, therefore, had not time to strike a medal for these as they could have done for other emperors who reigned longer. Hence, on the reverse of a medal of Marius, who reigned only three days, there is PACATOR ORBIS, which shows that at that time they had reverses ready fabricated, to be applied as occasion might require.

VI. *Plated medals, or those which have clefts.*—It has been already remarked, that many true medals are cracked in the edges, owing to the repeated strokes of the hammer, and the little degree of ductility which the metal possesses. This the forgers attempt to imitate by a file; but it is easy to distinguish between the natural and artificial cleft, by means of a small needle. The natural cleft is wide at the extremity, and appears to have a kind of almost imperceptible filaments; the edges of the crack corresponding with each other in a manner which no art can imitate.

The plated medals which have been forged in ancient times were long supposed to be capable of resisting every effort of modern imitation; but latterly some ingenious rogues thought of piercing false medals of silver with a red-hot needle, which gave a blackness to the inside of the coin, and made it appear plated to an injudicious eye. This fraud, however, is easily distinguished by scraping the inside of the metal. But it is nevertheless very difficult to distinguish the forgeries of rude money when not cast; and Mr Pinkerton gives no other direction than to consult a skilful medallist. Indeed, notwithstanding all the direc-

Medals. tions already given, this seems to be a resource which cannot by any means with safety be neglected. A real and practical knowledge of coins is only to be acquired by seeing a great number, and comparing the forged with the genuine. It cannot, therefore, be too much recommended to the young connoisseur, who wishes to acquire knowledge in this way, to visit all the sales and cabinets he can, and to look upon all ancient medals with a very microscopic eye. By these means only is to be acquired that ready knowledge which enables one at the first glance to pronounce upon a forgery, however ingenious. Nor let it be concluded from this that the science of medals is uncertain; for no knowledge is more certain and immediate, when it is properly studied by examination of the real objects. A man who buys coins, trusting merely to his theoretic perusal of medallic books, will find himself wofully mistaken. He ought first to study coins, where they can only be studied, in themselves. Nor need it be matter of wonder, or held to imply caprice, that a medallist of skill should at one perception pronounce upon the genuineness or spuriousness of a medal; for the powers of the human eye, employed in certain lines of science, are amazing. Hence a student can distinguish a book amongst a thousand similar and quite alike to every other eye; and, in the same way, the medallist can say in an instant, "This is a true coin, and this is a false," though to other people no distinction be perceptible.

Forgeries of modern coins and medals, Mr Pinkerton observes, are almost as numerous as of the ancient. The satirical coin of Louis XII. PERDAM BABYLONIS NOMEN, is a remarkable instance; the false coin is larger than the true one, and bears the date 1512. The rude coins of the middle ages are very easily forged, and forgeries have accordingly become common. Forged coins of Alfred and other early princes of England have appeared, some of which have been done with great art. The two noted English pennies of Richard I. are of this stamp, and yet have imposed upon Folkes and Snelling, who have published them as genuine in the two best books upon English coins. But they were fabricated by a Mr White of Newgate Street, a noted collector, who contaminated an otherwise fair character by such practices. Such forgeries, though easy, require a skill in the history and coinage of the times, which luckily can hardly fall to the lot of a common Jew or mechanical forger. But the practice is detestable, were no gain proposed; and they who stoop to it must suppose, that to embarrass the path of any science with forgery and futility, implies no infamy. In forgeries of ancient coin, the fiction is perhaps sufficiently atoned for by the vast skill required; and the artist may plausibly allege that his intention was not to deceive, but to excite his utmost powers, by an attempt to rival the ancient masters. But no possible apology can be made for forging the rude money of more modern times. The crime is certainly greater than that which leads the common coiner to the gallows; inasmuch as it is committed with more ease, and the profit is incomparably larger.

VIII.—*Of the Value of Medals.*

All ancient coins and medals, though equally genuine, are not equally valuable. In medals, as well as in everything else, the scarcity of a coin stamps a value upon it which cannot otherwise be derived from its intrinsic worth. There are usually reckoned four or five degrees of rarity, the highest of which is called *unique*. The cause is generally ascribed to the fewness of the number thrown off originally, or to their having been called in, and recoined in another form. To the former cause Mr Pinkerton ascribes the scarcity of the copper of Otho and the gold of Fescennius Niger; to the latter that of the coinage of Caligula, though this last is not of singular rarity; which shows that even the power of the Roman senate could not annihilate an established money, and that the first cause of rarity, arising from the small quantity originally struck, ought to be regarded as the principal. Medals.

In the ancient cities Mr Pinkerton ascribes the scarcity of coin to the poverty or the smallness of the state; but the scarcity of ancient regal and imperial coins arises principally from the shortness of the reign, and sometimes from the superabundance of money before, which rendered it almost unnecessary to coin any money during the reign of the prince. An example of this we have in the scarcity of the shillings of George III. which shows that shortness of reign does not always occasion a scarcity of coin; and thus the coins of Harold II. who did not reign a year, are very numerous, whilst those of Richard I. who reigned ten, are almost unique.

Sometimes the rarest coins lose their value, and become common. This our author ascribes to the high price given for them, which tempts the possessors to bring them to market; but chiefly to the discovering of hoards of them. The former cause operated in regard to Queen Anne's farthings, some of which formerly sold at five guineas; nay, if we could believe the newspapers, one of them was some years ago sold for L.960; the latter operated in respect to the coins of Canute the Danish king of England, which were very rare till a hoard of them was discovered in the Orkneys. As discoveries of this kind, however, produce a temporary plenty, so, when they are dispersed, the former scarcity returns; whilst, on the other hand, some of the common coins become rare through the mere circumstance of neglect.

As double the number of copper coins of Greek cities are to be met with that there are of silver, the latter are of consequence much more esteemed; but the reverse is the case with those of the Greek princes. All the Greek civic coins of silver are very rare, excepting those of Athens, Corinth, Messana, Dyrrhachium, Massilia, Syracuse, and some others. Of the Greek monarchic coins, the most rare are the tetradrachms of the kings of Syria, the Ptolemies, the sovereigns of Macedonia and Bithynia, excepting those of Alexander the Great and Lysimachus. Those of the kings of Cappadocia are of a small size, and scarcely to be met with. Of those of Numidia and Mauritania, the coins of Juba the father are common; but those of the son, and nephew Ptolemy, are scarce. Coins of the kings of Sicily, Parthia, and Judæa, are rare; the last very much so. We meet with no coins of the kings of Arabia and Comagene excepting in brass; those of the kings of Bosphorus are in electrum, and a few in brass, but all of them rare; as are likewise those of Philetenis king of Pergamus, and of the kings of Pontus. In the year 1777, a coin of Mithridates sold for L.26. 5s. Didrachms of all kings and cities are scarce, excepting those of Corinth and her colonies; but the gold coins of Philip of Macedonia, Alexander the Great, and Lysimachus, as has already been observed, are common. The silver tetradrachms of all kings bear a very high price. The didrachm of Alexander the Great is one of the scarcest of the smaller Greek silver coins; some of the other princes are not uncommon.

In most cases the copper money of the Greek monarchs is scarce; but that of Hiero I. of Syracuse is uncommonly plentiful, as well as that of several of the Ptolemies.

The most rare of the consular Roman coins are those restored by Trajan; of the others, the gold consular coins are the most rare, and the silver the most common; excepting the coin of Brutus with the cap of liberty, already mentioned, and some others. Some of the Roman imperial coins are very scarce, particularly those of Otho in brass, nor indeed does he occur at all on any coin struck at Rome; but the reason of this may with great probabi-

Medals.

lity be supposed to have been the shortness of his reign. His portrait upon the brass coins of Egypt and Antioch is very bad, as well as almost all the other imperial coins of Greek cities. The best likeness is on his gold and silver coins; the latter of which are very common. The Greek and Egyptian coins are all of small and middling sizes, and have reverses of various kinds; those of Antioch have Latin legends, as well as most of the other imperial coins of Antioch. They have no other reverse but the SC in a wreath, excepting in one instance or two of the large and middle brass, where the inscriptions are in Greek. Latin coins of Otho in brass, with figures on the reverse, are certainly false, though in the cabinet of D'Ennery at Paris there was an Otho in middle brass restored by Titus, which was esteemed genuine by connoisseurs.

The leaden coins at Rome are very scarce. Most of them are pieces struck or cast upon occasion of the saturnalia; others are tickets for festivals and exhibitions, both public and private. The common tickets for theatres were made of lead, as were the *contorniati*, perpetual tickets, like the English silver tickets for the opera. Leaden medallions are also found below the foundations of pillars and other public buildings, where they had been placed to perpetuate the memory of the founders. From the time of Augustus also we find that leaden seals were used. The work of Ticorini upon this subject, entitled *Piombi Antiochi*, is much recommended by Mr Pinkerton.

The Roman coins, which have been blundered in the manner formerly mentioned, are very rare, and undeservedly valued by the connoisseurs. The blunders in the legends of these coins, which in all probability are the mere effects of accident, have been so far mistaken by some medallists, that they have given rise to imaginary emperors who never existed. A coin of Faustina, which has on the reverse SOUSTI. S. C. puzzled all the German antiquaries, till at last Klotz gave it the following facetious interpretation: *Sine omni utilitate sectamini tantas ineptias.*

The heptarchic coins of England are generally rare, except those called *stycas*, which are very common, as well as those of Burgred king of Mercia. The coins of Alfred which bear his bust are scarce, and his other money much more so. Those of Hardyknute are so rare that it was even denied that they had an existence; but Mr Pinkerton informs us that there are three in the British Museum, upon all of which the name HARTHCANUT is quite legible. No English coins of King John are to be met with, though there are some Irish ones; and only French coins of Richard I. are met with. "Leake," says Pinkerton, "made a strange blunder, in ascribing coins of different kings with two faces, and otherwise spoiled in the stamping, to this prince, in which, as usual, he has been followed by a misled number."

Coins of Alexander II. of Scotland are rather scarce, but those of Alexander III. are more plentiful. Those of John Baliol are rare, and none of Edward Baliol are now to be found.

IX.—*Arrangement of Medals, with the Instruction to be derived from them.*

Having thus given a full account of every thing generally relating to medals, we now proceed to give some particulars respecting their arrangement, and the entertainment which a medallist may expect from the trouble and expense he incurs in making a collection.

It has already been observed, that one of the principal uses of medals is the elucidation of ancient history. Hence the arrangement of his medals is the first thing that must occur in the formation of a cabinet. The most ancient medals with which we are acquainted are those of Alexander I. of Macedonia, who began to reign about 501 years before Christ. The series ought consequently to commence with him, and to be succeeded by the medals of Sicily, Caria, Cyprus, Heraclia, and Pontus. Then follow Egypt, Syria, the Cimmerian Bosphorus, Thrace, Bithynia, Parthia, Armenia, Damascus, Cappadocia, Paphlagonia, Pergamus, Galatia, Cilicia, Sparta, Pæonia, Epirus, Illyricum, Gaul, and the Alps, including the space of time from Alexander the Great to the birth of Christ, and which is to be accounted the third medallic series of ancient monarchs. The last series comes down to the fourth century, including some of the monarchs of Thrace, Bosphorus, and Parthia, with those of Comagene, Edessa or Osrhoene, Mauritania, and Judæa. A most distinct series is formed by the Roman emperors from Julius Cæsar to the destruction of Rome by the Goths; nay, for a much longer period, were it not that towards the latter part of it the coins become so barbarous as to destroy the beauty of the collection. Many series may be formed of modern potentates.

Medals.

By means of medals we can with great certainty determine the various ornaments worn by ancient princes as badges of distinction. The Grecian kings have generally the diadem, without any other ornament; and though in general the side of the face is presented to view, yet in some very ancient Greek and Roman consular coins, full faces of excellent workmanship are met with. On several coins also two or three faces are to be seen, and these are always accounted very valuable.

The diadem, which was no more than a ribbon tied round the head with a floating knot behind, adorns all the Grecian princes from first to last, and is almost an infallible mark of sovereign power. In the Roman consular coins it is seen in conjunction with Numa and Ancus, but never afterwards till the time of Licinius, the colleague of Constantine. Diocletian, indeed, according to Mr Gibbon, first wore the diadem; but his portrait upon coins is never adorned with it. So great an aversion had the Romans to kingly power, that they rather allowed their emperors to assume the radiated crown, the symbol of divinity, than to wear a diadem; but after the time of Constantine it becomes common. The radiated crown appears first on the posthumous coins of Augustus as a mark of deification, but in somewhat more than a century it became common.

The laurel crown, at first a badge of conquest, was afterwards permitted by the senate to be worn by Julius Cæsar, in order to hide the baldness of his head. From him all the emperors appear with it on their medals, even to our own times. In the lower empire the crown is sometimes held by a hand above the head, as a mark of piety. Besides these, the naval, mural, and civic crowns appear on the medals both of emperors and of other eminent men, being intended to denote their great actions. The laurel crown is also sometimes worn by the Greek princes. The Arsacidæ of Parthia wear a kind of sash round the head, with their hair in rows of curls like a wig. The Armenian kings have the *tiara*, a kind of cap which was esteemed as the badge of imperial power in the East. Conical caps are seen upon the medals of Xerxes, a petty prince of Armenia, and those of Juba the father, the former having a diadem around it.

The impious vanity of Alexander and his successors, in assuming divine honours, is manifest on their medals, where various symbols of divinity are met with. Some of them have the horn behind their ear, either to denote their strength, or that they were the successors of Alexander, to whom this badge might be applied as the son of Jupiter Ammon. This, however, Mr Pinkerton observes, is the only one of those symbols which certainly denote an earthly sovereign, it being doubtful whether the rest are not all figures of gods. According to Eckhet, even the horn and diadem belong to Bacchus, who invented the latter to

Medals. cure his headachs; and, according to the same author, the only monarch who appears on coins with the horn is Lysimachus. We are informed, however, by Plutarch, that Pyrrhus had a crest of goats' horns to his helmet; and the goat, we know, was a symbol of Macedonia. Perhaps the successors of Alexander wore this badge of the horn in consequence. The helmet likewise frequently appears on the heads of sovereigns, and Constantine I. has helmets of various forms curiously ornamented.

The diadem is worn by most of the Greek queens, as by Orodaltis, daughter of Lycomedes, king of Bithynia; and although the Roman empresses never appear with it, yet this is more than compensated by the variety of their headdresses. Sometimes the bust of an empress is supported by a crescent, to imply that she was the moon, as her husband was the sun of the state. The toga or veil drawn over the face, at first implied that the person was invested with the pontifical office; and accordingly we find it on the busts of Julius Cæsar, while pontifex maximus. It likewise implies the augurship, the augurs having a particular kind of gown called *lana*, with which they covered their heads when observing an omen. In latter times this implies only consecration, and is common in coins of empresses. It is first met with on the coins of Claudius Gothicus as the mark of the consecration of an emperor. The *nimbus* or glory, now appropriated to saints, has been already mentioned. It is as ancient as Augustus, but is not to be met with upon many of the imperial medals, even after it began to be appropriated to them. There is a curious coin, which has upon the reverse of the common piece, with the head of Rome, URBS ROMA, in large brass; Constantine I. sitting amidst Victories and Genii, with a triple crown upon his head for Europe, Asia, and Africa, with the legend SECURITAS ROMÆ.

In general only the bust is given upon medals, though sometimes half the body or more, in which latter case the hands often appear with ensigns of majesty in them, such as the globe, said to have been introduced by Augustus as a symbol of universal dominion; the sceptre, sometimes confounded with the consular staff; a roll of parchment, the symbol of legislative power; and an handkerchief, expressive of the power over the public games, where the emperor gave the signal. Some princes hold a thunderbolt, showing that their power on earth was equal to that of Jupiter in heaven, while others hold an image of Victory.

Medals likewise afford a good number of portraits of illustrious men; but they cannot easily be arranged in chronological order, so that a series of them is not to be expected. It is likewise vain to attempt the formation of a series of gods and goddesses as found upon ancient coins. Mr Pinkerton thinks it much better to arrange them under the several cities or kings whose names they bear. A collection of the portraits of illustrious men may likewise be formed from medals of modern date.

The reverses of ancient Greek and Roman coins afford an infinite variety of instruction and amusement. They contain figures of deities at full length, with their attributes and symbols, public symbols and diversions, plants, animals, &c.; and in short almost every object of nature or art. Some have the portrait of the queen, son, or daughter of the prince whose image appears on the face obverse; and these are esteemed highly by antiquaries, not only because every coin stamped with portraits on both sides is accounted valuable, but because they render it certain that the person represented on the reverse was the wife, son, or daughter of him who appears on the obverse; by which means they assist greatly in the adjustment of a series. Some, however, with two portraits are common, as Augustus, the reverse of Caligula; and Marcus Aurelius, the reverse of Antoninus Pius.

We find more art and more design in the reverses of the Roman medals than in those of the Greek; but, on the other hand, the latter exhibit more exquisite relief and workmanship. The very ancient coins have no reverses, excepting a rude mark struck into the metal, resembling that of an instrument with four blunt points upon which the coin was struck, and this was owing to its having been fixed by such an instrument on that side to receive the impression upon the other. To this succeeds the image of a dolphin, or some small animal, in one of the departments of the rude mark, or in a hollow square; and this again is succeeded by a more perfect image, without any mark of the hollow square. Some of the Greek coins are hollow in the reverse, as those of Caulonia, Crotona, Metapontum, and some other ancient cities of Magna Græcia. About 500 before Christ perfect reverses appear on the Greek coins, of exquisite relief and workmanship. "The very muscles of men and animals," says Pinkerton, "are seen, and will bear inspection with the largest magnifier as ancient gems. The ancients certainly had not eyes different from ours, and it is clear that they must have magnified objects. A drop of water forms a microscope, and it is probable this was the only one of the ancients. To Greek artists we are indebted for the beauty of the Roman imperial coins, and these are so highly finished, that on some reverses, as on that of Nero's decursion, the *adventus* and *progressio* of various emperors, the *fundator pacis* of Severus, the features of the emperor, riding or walking, are as exact as upon the obverse. But though the best Greek artists were called to Rome, yet the Greek coins under the Roman emperors are sometimes well executed, and always full of variety and curiosity. No Roman or Etruscan coins have been found of the globular form, or indented on the reverse like the early Greek. The first Greek are small pieces of silver, whilst the Roman are large masses of copper. The former are struck, the latter cast in moulds. The reverses of the Roman coins are very uniform, the prow of a ship, a car, or the like, till about the year 100 before Christ, when various reverses appear on their consular coins in all metals. The variety and beauty of the Roman imperial reverses are well known. The medallist values much those which have a number of figures, as the *Puellæ Faustinianæ* of Faustina, a gold coin no larger than a sixpence, which has twelve figures; that of Trajan, *regna assignata*, has four; the *congiarium* of Nerva five; the allocution of Trajan seven; that of Hadrian ten; and that of Probus twelve. Some Roman medals have small figures on both sides, as the *Apollini sancto* of Julian II. But these have not received any peculiar name amongst the medallists. Others have only a reverse, as the noted *spintriati*, which have numerals I., II., &c. on the obverse.

The *names* of the deities represented on the reverses of Greek coins are never expressed; perhaps, as Mr Pinkerton supposes, out of piety, a symbolical representation of their attributes being all that they thought proper to delineate; but the Roman coins always express the name, frequently with an adjunct, as VENERI VICTRICI. In others, the name of the emperor or empress is added; as PUDICITIÆ AUGUSTÆ, round an image of modesty, and VIRTUS AUGUSTI, a legend for an image of virtue. The principal symbols of the divine attributes to be met with upon the Greek medals are as follow:

1. Jupiter is known on the coins of Alexander the Great by his eagle and thunderbolts; but when the figure occurs only on the obverses of coins, he is distinguished by a laurel crown, and placid bearded countenance. Jupiter Ammon is known by the ram's horn twisting round his ear; a symbol of power and strength assumed by some of the successors of Alexander the Great, particularly by Lysimachus. 2. Neptune is known by his trident, his dolphin, or his being drawn by sea-horses; but he is seldom met with on the Grecian coins. 3. Apollo is distinguished by a harp, a branch of laurel, or a tripod, and sometimes by a bow and arrows. In the character of the sun his head is surround-

Medals. ed with rays; but when the bust only occurs, he has a fair young face, and is crowned with laurel. He is frequently found on the coins of the Syrian princes. 4. Mars is distinguished by his armour, and sometimes by a trophy on his shoulders. His head is armed with a helmet, and he has a ferocious countenance. 5. Mercury is represented as a youth, with a small cap on his head, and wings behind his ears and on his feet. He is known by the cap, which resembles a small hat, and the wings. He appears also with the caduceus, or wand twined with serpents, and the *marsupium* or purse, which he holds in his hand. 6. Æsculapius is known by his bushy beard, and his leaning on a club with a serpent twisted round it. He sometimes occurs with his wife Hygeia or Health, and their son *Telesphorus* or Convalescence between them. 7. Bacchus is known by his crown of ivy or vine, his diadem and horn, with a tiger and satyrs around him. 8. The figure of Hercules is common on the coins of Alexander the Great, and has frequently been mistaken for that of the prince himself. He appears sometimes as a youth, and sometimes with a beard. He is known by the club, the lion's skin, and remarkable apparent strength; sometimes he has a cup in his hand; and a poplar tree, as a symbol of vigour, is sometimes added to the portrait. 9. The Egyptian Serapis is known by his bushy beard, and a measure upon his head. 10. Apis is delineated in the form of a bull, with a flower of the lotus, the water-lily of the Nile, supposed by Macrobius to be a symbol of creation; and Jamblichus tells us, that Osiris was thought to have his throne in it. 11. Harpocrates, the god of silence, appears with his finger on his mouth; sometimes with the systrum in his left hand, a symbol common to most of the Egyptian deities. 12. Canopus, another Egyptian deity, appears in the shape of a human head placed on a kind of pitcher. "This deified pitcher," says Mr Pinkerton, "seems to refer to an anecdote of ancient superstition, which, I believe, is recorded by Plutarch. It seems some Persian and Egyptian priests had a contest which of their deities had the superiority. The Egyptian said, that a single vase, sacred to Serapis, would extinguish the whole power of the Persian deity of fire. The experiment was tried; and the wily Egyptian, boring holes in the vase and stopping them with wax, afterwards filled the vase with water, which, gushing through the holes as the wax melted, extinguished the Persian deity. Hence the vase was deified." 13. The *Holy Senate* and *Holy People* appear frequently on the Greek imperial coins, sometimes represented as old men with beards, at others as youths.

The goddesses represented on medals are the following. 1. Juno, represented by a beautiful young woman, sometimes with a diadem, sometimes without any badge, which is reckoned a sufficient distinction, as the other goddesses all wear badges. Sometimes she appears as the goddess of marriage, and is then veiled to the middle, and sometimes to the toes. She is known by the peacock, a bird sacred to her, from the fable of Argus. 2. Minerva is very common upon the coins of Alexander the Great, and her bust has been mistaken by the celebrated painter Le Brun for the hero himself. She is very easily distinguished by the helmet. Her symbols are, her armour; the spear in her right hand, the ægis, with a Medusa's head, in her left, and an owl commonly standing by her. 3. Diana of Ephesus is commonly represented on the Greek imperial coins, and appears with a great number of breasts, supposed to denote universal nature. She is supported by two deer, and carries a pannier of fruit upon her head. The bust of this goddess is known by the crescent upon her brow, and sometimes by the bow and quiver at her side. 4. Venus is known by an apple, the prize of beauty, in her hand. Sometimes she is distinguished only by her total want of dress; but she is always to be known by her extraordinary beauty, and is sometimes adorned with pearls about the neck. 5. Cupid is sometimes met with on the Syrian coins, and is known by his infancy and wings. 6. Cybele is known by a turreted crown and lion, or is seen in a chariot drawn by lions. 7. Ceres is known by her garland of wheat, and is common on the Sicilian coins, that island being remarkable for its fertility. Sometimes she has two serpents by her, and sometimes she is drawn by them in a chariot. She carries in her hands the torches with which she is fabled to have gone in search of her daughter Proserpine. 8. Proserpine herself is sometimes met with upon coins, with the name of κορη, or the girl. 9. The Egyptian Isis has a bud or flower on her head, a symbol of the perpetual bloom of the inhabitants of heaven. She carries also a systrum in her hand. 10. The Sidonian Astarte appears on a globe supported on a chariot with two wheels, drawn by two horses. Medals.

These are the deities most commonly represented on the Greek coins. The more uncommon are, Saturn with his scythe, or with a hook on the Heraclian coins; and Vulcan with his tongs, on the reverse of a coin of Thyatira, represented at work in the presence of Minerva. Adranus, a Sicilian god, is sometimes represented on coins with a dog. Anubis, an Egyptian deity, has a dog's head. Atis is known by his Phrygian bonnet; Castor and Pollux by a star upon the head of each; Dis, by his old face, dishevelled hair and beard, and a hook; Flora by her crown of flowers; Nemesis by her wheel; and Pan by his horns and ears belonging to some kind of beast.

There are likewise to be found on medals many different symbols by themselves, the most remarkable of which we shall give in the following table, with their signification:—

Symbols.	Significations.
1. Vases with sprigs	Solemn games.
2. Small chest or hamper, with a serpent leaping out	Mystic rites of Bacchus.
3. Anchor on Seleucian medals	Coin struck at Antioch, where an anchor was dug up.
4. Apollo on Syrian coins, on an inverted hamper	Covered tripod.
5. Bee	Aristeus the son of Apollo.
6. Laurel	Apollo.
7. Reed	A river.
8. Ivy and grapes	Bacchus.
9. Poppy	Ceres and Proserpine.
10. Corn	Ceres.
11. Owl and olive	Minerva.
12. Dove	Venus.
13. Torch	Diana, Ceres, or Proserpine.
14. Mudnis, or conic stone	The sun, Belus, or Venus.
Symbols of Countries, &c.	
15. Pomegranate flowers	Rhodes.
16. Owl	Athens.
17. Pegasus	Corinth.
18. Wolf's head	Argos.
19. Bull's head	Bœotia.
20. Minotaur's head and labyrinth	Crete.
21. Horse's head	Pharsalia.
22. Lion	Marseilles.
23. Tortoise	Peloponnesus.
24. Sphinx	Scio.
25. Three legs joined, as in the Isle of Man money	Sicily.
26. Horse	Thessaly.

Medals.	Symbols.	Significations.
	27. The crescent	Byzantium.[1]
	28. Bull	Supposed to be a river.
	29. Ensign, with the letters COL	A colony drawn from one legion.
	30. Bull	Apis, strength or security.
	31. Caduceus	Peace and concord.
	32. Cornucopiæ	Abundance.
	33. Pontifical hat	Priesthood.
	34. Parazonium	Batoon of command.
	35. Globe on an altar with three stars	The world preserved by the gods for the three sons of Constant I.
	36. Fort and gate	Security.
	37. Tribuli, a kind of chevaux de frize	Unknown.
	38. Altar or tripod	Piety.
	39. Dolphin	Apollo.
	40. Lectisternia	Festivals.
	41. Lituus, or twisted wand	Augurship.
	42. Apex, or cap with strings	Pontificate.
	43. Thensa, or chariot employed to carry images	Consecration of an empress.
	44. Peacock	Ditto.
	45. Eagle	Consecration of an emperor.

The legends impressed upon medals are designed as explanations of them; but as the compass of even the largest coins does not admit of any great length of inscription, it has always been found necessary to use abbreviations; and in readily deciphering these consists a considerable part of the difficulty of the science. This, however, is greater in the Roman than in the Greek medals; for the Greeks commonly insert as much of the word as is sufficient to enable us easily to understand its meaning; but it is common for those who attempt to explain letters which do not often occur, to fall into very ridiculous errors. Of this Mr Pinkerton gives a most remarkable instance in Fortunius Licetus, a learned man, who finding upon a coin of Hadrian the letters A. IΔ, signifying the 14th year of that emperor's reign, imagined that they signified *Lucernas invenit Delta;* "Delta invented lanthorns;" and thence ascribed the origin of lanthorns to the Egyptians. Tables explaining the meaning of the abbreviations found upon medals have been published by Patin, Ursatus, and others.

X.—*Of Medallions, &c.*

Besides the ordinary coins of the ancients, which passed in common circulation through the country, there were others of a larger size, which are now termed *medallions.* These were struck on the commencement of the reign of a new emperor, and on other solemn occasions; and frequently also, by the Greeks in particular, as monuments of gratitude or of flattery. Sometimes they were mere trial or pattern pieces; and, after the time of Maximian, these abound, with the words *Tres Monetæ* on the reverse. The common opinion is, that all the Roman pieces of gold exceeding the denarius aureus, all in silver exceeding the denarius, and all in brass exceeding the sestertius, went under the denomination of *medallions;* but Mr Pinkerton thinks that many of these large pieces passed in circulation, though not very commonly, as our five and two guinea-pieces, silver crowns, &c. do or did in this country. The finest medallions were presented by the mint-masters to the emperor, and by the emperor to his friends, as specimens of elegant workmanship. The best we have at present are of brass, and many of them composed of two sorts of metal, the centre being copper, with a ring of brass around it, or the contrary; and the inscription is sometimes confined to one of the metals, sometimes not. There is a remarkable difference between the Greek and Roman medallions in point of thickness; the latter being frequently three or four lines thick, whilst the former seldom exceed one. Very few medallions, however, were struck by the Greeks before the time of the Roman emperors; but the Greek medallions of the emperors are more numerous than those of the Romans themselves. All these pieces, however, are of such high price that very few private individuals are able to purchase them. In the last century Christina queen of Sweden procured about 300. In the king of France's collection there are 1200, a number formerly supposed not to exist; and Dr Hunter's collection contains about 400, exclusive of the Egyptian. Besides these large pieces, there are smaller ones, of a size somewhat larger than our half-crowns; which by Italian medallists are called *medaglioncini*, or small medallions. They are still scarcer than the large kind.

There is still a third kind, which have almost escaped the notice of medallists, viz. the small coins or *missilia* scattered amongst the people on solemn occasions; such as those struck for the slaves on account of the saturnalia, counters for gaming, tickets for baths and feasts, and tokens in copper and in lead. These are distinguished by Mr Pinkerton by the name of *medalets.* Many, or perhaps almost all, of those struck for the saturnalia were satirical, as the slaves had then a license to ridicule not only their masters, but any person whatsoever. Mr Pinkerton mentions one of the most common pieces of this kind, which has on the obverse the head of an old woman veiled, with a laurel crown; the reverse contains only SC within a wreath. Baudelot is of opinion that it is the head of Acca Laurentia, the nurse of Romulus, to whom a festival was ordained. "Perhaps," says Pinkerton, "it was struck in ridicule of Julius Cæsar; for the manner of the laurel crown, and its high appearance over the head, perfectly resemble that of Julius on his coins." Some have a ship upon one side; on the reverse, T, or a cross, which was the image of Priapus, and occasioned many false invectives against the first Christians, who paid profound respect to the cross. Some pieces have the heads of the emperors upon one side; on the reverse only numerals, III. IV. V. &c., and the noted *spintriati* of Tacitus. Both these kinds appear to have been tickets for the baths, as the number seems to denote the particular bath. Some have the head of a girl with a vessel used at the baths in her hand. The spintriati are so immodest that few of them will bear mention. But some are merely ludicrous; as one which has an ass with a bell about his neck, and a soldier riding him; and another with two figures hoisting a woman in a basket into the air. Of those that will just bear mention, is a man with titles around him, as chief of the games, and a woman in ridicule of the modest bath-girl above mentioned. There is also one marked XIX, on which appears an imperator triumphing in a car,

[1] This appears on the early coins of Byzantium, with the legend BYZANTIN. ΣΩΤ. "the preserver of Byzantium." The reason of this was, that when Philip of Macedonia besieged the city, and was about to storm it in a cloudy night, the moon shone out on a sudden and discovered him; by which means the inhabitants had time to collect their forces and repulse him. The Turks, on entering Constantinople, found this badge in many places; and suspecting some magical power in it, assumed the symbol and its power to themselves, so that the crescent is now the chief Turkish ensign.

Medals. which is placed on the back of a camel; and behind the imperator is a monkey mimicking him.

A fourth class of medals are called *contorniati*, from the Italian *contorniato*, encircled; because of the hollow circle which commonly runs around them. They are distinguished from medallions by their thinness, faint relief, reverses sometimes in relief, sometimes hollow, and in general by the inferiority in their workmanship. The opinions of medallists concerning these pieces are very various. Some suppose them to have been struck by Gallienus, to the memory of illustrious men and celebrated *athletæ*, at the time when he caused all the consecration coins of his predecessors to be restored; and others ascribe their invention to Greece, &c.; but Mr Pinkerton is of opinion that they were only tickets for places at public games. Many of them, notwithstanding their inferior workmanship, are very valuable on account of their preserving the portraits of some illustrious authors of antiquity, which are nowhere else to be found. Much dependence, however, cannot be put on the portraits of Greek authors and eminent men found upon some of them; for although we know that the busts of Sallust, Horace, &c. must have been struck when their persons were fresh in the memory of the artists, yet it was otherwise with Homer, Solon, Pythagoras, &c. who are to be found upon some of them. Even these, however, are valuable, as being ancient and perhaps traditional portraits of these great men. The last whose portraits are supposed to have been delineated in this way are Apollonius Tyaneus who flourished in the time of Domitian, and Apuleius in that of Marcus Antoninus. Mr Pinkerton thinks it a confirmation of his opinion concerning these medals, that the reverses always contain some device alluding to public games, as that of a charioteer driving a chariot, &c.

XI.—*Directions for forming Cabinets.*

We must now proceed to the last part of our subject, viz. that of giving directions for the formation of cabinets. As we have already seen that the formation of any one must be attended with very considerable expense, it is necessary for every one who attempts this to proportion the cabinet to his own circumstances. There are, properly speaking, three kinds of cabinets. 1. Those meant to contain a coin of every sort that has been issued from the mint in every age and country; but this, which may be called the large and complete cabinet, is not to be purchased by private persons. That of Dr Hunter, now in the possession of the university of Glasgow, is perhaps one of the best private cabinets ever known. 2. The smaller cabinet may be supposed to consist only of middle and small Roman brass, English pennies, groats, &c., with a few medals of the more valuable kind. 3. The smallest kind is called a *casket* of medals, and does not consist of above 1000 at most of various kinds; and consequently the expense must depend upon the pleasure of the proprietor.

In the formation of the grand cabinet, it must be observed that the Greek medals of every denomination do not admit of any arrangement by the metals like the Roman; no regular series of this description being met with even in the most opulent cabinets. Hence in all collections the civic coins are ranged according to an alphabetical, and the monarchic in a chronological order. The same rule is to be observed in the Roman consular medals; they are ranged, like the coins of the Greek cities, in an alphabetical series of the families. The Roman imperial coins are those only which are capable of being arranged according to sizes and metals. Even from this must be excepted the minimi, or the very smallest coins, which are so scarce that the only regular series of them in the world is that belonging to the king of Spain, which was formed by a most skilful French medallist, and consists of all the metals. The arrangement of a grand cabinet, according to Mr Pinkerton, is as follows. 1. The coins of cities and of free states in alphabetical order, whether using Greek, Roman, Punic, Etruscan, or Spanish characters. 2. Kings in chronological series, both as to foundation of empire and seniority of reign. 3. Heroes, heroines, founders of empires, and cities. 4. Other illustrious persons. 5. Roman asses. 6. Coins of families, commonly called consular. 7. Imperial medallions. 8. Imperial gold. 9. Imperial *minimi* of all metals. 10. Imperial silver. 11. Imperial first brass. 12. Second brass. 13. Third brass. 14. Colonial coins, which are all of brass. 15. Greek cities under the emperors, of all metals and sizes. In a smaller cabinet they may be put with the Roman, according to their metal and size. Those without the emperor's head go to class 1, though struck in Roman times. 16. Egyptian coins struck under the Roman emperors, of all metals and sizes. They are mostly of a base metal called by the French *patin*; it is a kind of pot-metal or brittle brass. 17. Contorniati, or ticket medals. 18. Coins of Gothic princes, &c. inscribed with Roman characters. 19. Coins of southern nations using uncommon alphabets; as the Persian, Punic, Etruscan, and Spanish. 20. Coins of northern nations using uncommon characters; as the Runic and German. Medals.

In the modern part no series can be formed of copper that will reach backwards above two centuries; but sequences (chronological series) of gold and silver may be arranged of all the different empires, kingdoms, and states, as far as their several coinages will allow. Those of England and France will be the most perfect. Modern silver is commonly arranged in three sequences; the dollar, the groat, and the penny sizes. The medals of each modern country ought of course to be separated; though it is best to arrange each set in chronological order, let their size of metal be what it may. It may be remarked here, that our modern medals of the size of a tea-saucer are only so many monuments of barbarism. The ancient medallions are almost universally but little larger than our crown-piece, though three or four of them may extend to about two inches diameter, but very many modern medals to four inches and more. A large medal always indicates an ignorant prince or an ignorant artist. Into the size of a crown-piece the ancients threw more miracles in this way than will ever be found in such monstrous productions.

These directions will likewise apply to the formation of a cabinet of the second kind; but if the collector means to form a series of large Roman brass, he will find the coins of four or five emperors so scarce as not to be attainable in that series, at any price. He must therefore supply their places with middle brass, as is allowed with regard to Otho, even in the best cabinets; there not being above three coins of that emperor in large brass known in the world, whereas of the middle brass two or three hundred are still extant. For this reason Mr Pinkerton concludes, that in cabinets of the second class, the collector may mingle the large and second brass together as he thinks proper, in order to save expense; though it would not do so well to unite such disproportionate sizes as the large and small. "In the small sequence, however," says he, "there can be no harm in his mixing gold, silver, and brass, as chance or curiosity may lead him to purchase any of these metals. And though your starched bigoted medallists may sneer because such a sequence would controvert his formal and narrow way of thinking, common sense will authorize us to laugh at the pedant in our turn, and to pronounce such a series more various, rich, and interesting, than if the collector had arranged only one metal, and rejected a curious article because he did not collect gold or silver. In like manner, if, in the modern part of the smaller cabinet, any coin of a series is of high price, or of

Medallion || Medea.

bad impression, there can be no impropriety in putting another of the same reign, which is cheaper or better executed, though of a different denomination or of a little larger size. In short, the collector has no rules but in the Greek cities and Roman families, and to observe alphabetical order and chronology in every thing else.

Media.

MEDALLION, or MEDALION, a medal of an extraordinary size, supposed to be anciently struck by the emperors for their friends, and for foreign princes and ambassadors. But, that the smallness of their number might not endanger the loss of the devices they bore, the Romans generally took care to stamp the subject of them upon their ordinary coins. Medallions, in respect of the other coins, were the same as modern medals in respect of modern money; they were exempted from all commerce, and had no other value than what was set upon them by the fancy of the owner. Medallions are so scarce that a set cannot be made of them, even though the metals and sizes should be mixed promiscuously.

MEDEA, in fabulous history, a celebrated sorceress, daughter of Æetes king of Colchis. Her mother's name, according to the more received opinion of Hesiod and Hyginus, was Idyia, or, according to others, Ephyre, Hecate, Asterodia, Antiope, and Neæra. She was the niece of Circe. When Jason came to Colchis in quest of the golden fleece, Medea became enamoured of him, and it was to her well-directed labours that the Argonauts owed their preservation. Medea had an interview with her lover in the temple of Hecate, where they bound themselves by the most solemn oaths to eternal fidelity. No sooner had Jason overcome all the difficulties which Æetes had placed in his way, than Medea embarked with the conquerors for Greece. To stop the pursuit of her father, she tore to pieces her brother Absyrtus, and left his mangled limbs in the way through which Æetes was to pass. This act of barbarity some have attributed to Jason, and not to her. When Jason reached Iolchos, his native country, the return and victories of the Argonauts were celebrated with universal rejoicings; but Æson the father of Jason was unable to assist at the solemnity, on account of the infirmities of his age. Medea, at her husband's request, removed the weakness of Æson; and by drawing blood from his veins, and filling them again with the juice of certain herbs, she restored him to the vigour and sprightliness of youth. This sudden change in Æson astonished the inhabitants of Iolchos; and the daughters of Pelias were also desirous to see their father restored by the same power to the vigour of youth. Medea, willing to revenge the injuries which her husband's family had suffered from Pelias, increased their curiosity, and betrayed them into the murder of their father as preparatory to his rejuvenescence, which she afterwards refused to accomplish. This action greatly irritated the people of Iolchos, and Medea with her husband fled to Corinth to avoid their resentment. Here they lived for ten years with mutual attachment, when the love of Jason for Glauce the king's daughter interrupted their harmony, and Medea was divorced. Medea revenged the infidelity of Jason by causing the death of Glauce, and the destruction of her family. She also killed two of her children in their father's presence; and when Jason attempted to punish the barbarity of the mother, she fled through the air upon a chariot drawn by winged dragons. From Corinth Medea went to Athens, where, after she had undergone the necessary purification of her murder, she married King Ægeus, or (according to others) lived in an adulterous manner with him. From her conduct with Ægeus, Medea had a son who was called *Medus*. Soon afterwards, when Theseus wished to make himself known to his father, Medea, jealous of his fame and fearful of his power, attempted to poison him at a feast which had been prepared for his entertainment. Her attempts however failed of success, and the sight of the sword which Theseus wore by his side convinced Ægeus that the stranger against whose life he had so basely conspired was his own son. The father and the son were reconciled; and Medea, to avoid the punishment which her wickedness deserved, mounted her fiery chariot and disappeared through the air. Her aerial voyage terminated at Colchis, where, according to some, she was reconciled to Jason, who had sought her in her native country after her sudden departure from Corinth. She died at Colchis, as Justin mentions, when she had been restored to the confidence of her family. After death she married Achilles in the Elysian fields, according to the tradition mentioned by Simonides. The murder of Mermerus and Pheres, the youngest of Jason's children by Medea, is not to be attributed to the mother, according to Ælian, but to the Corinthians, who assassinated them in the temple of Juno Acræa. To avoid the resentment of the gods, and to deliver themselves from the pestilence which had visited their country after so horrid a massacre, they engaged the poet Euripides for five talents to write a tragedy, which cleared them of the murder, and represented Medea as the cruel assassin of her own children. And, besides, that this opinion might be the better credited, festivals were appointed, in which the mother was represented with all the barbarity of a fury, murdering her own sons.

MEDIA, now the province of Ghilan in Persia, once the seat of a powerful empire, was bounded, according to Ptolemy, on the north by part of the Caspian Sea; on the south by Persia, Susiana, and Assyria; on the east by Parthia and Hyrcania; and on the west by Armenia Major. It was anciently divided into the provinces of Tropatene, Charomithrene, Darites, Marciane, Amariace, and Syro-Media. By a later division, however, all these were reduced to two; the one being called *Media Magna*, and the other *Media Atropatia*, or simply *Atropatene*. Media Magna was bounded by Persis, Parthia, Hyrcania, the Hyrcanian Sea, and Atropatene, and contained the cities of Ecbatana, Laodicea, Apamea, Raga, Rageia or Ragea, &c. Atropatene lay between the Caspian Mountains and the Caspian Sea. This country originally took its name from Madai, the third son of Japhet; as is plain from Scripture, where the Medes are constantly called *Madai*. Amongst profane authors, some derive the name of Media from one Medus the son of Jason and Medea, and others from a city called *Media*. Sextus Rufus tells us that in his time it was called *Medena*, and from others we learn that it was also called *Aria*.

The government of the various tribes into which the country was divided was originally monarchical, and they seem to have had their own kings even in the earliest times. They were first brought under the Assyrian yoke by Pul, said to have been the founder of that monarchy, or by his immediate successor Tiglath-pileser. From the time of Pul, or Tiglath-pileser, who succeeded his father in the year 740 B. C., they remained subject to the Assyrians till about the latter end of the reign of Sennacherib, 710 B. C., when, emancipating themselves from Assyrian bondage, they fell into a state of anarchy. This circumstance, as Herodotus informs us, gave Esar-Haddon, or Assar-Hadon, who succeeded Sennacherib, an opportunity of reducing a great part of Media, if not the whole country, under subjection. This anarchy is supposed to have lasted one year; for Dejoces, called Arphaxad in the book of Judith, was killed by Saoduchius or Nebuchadonosor, in the year 656. From the commencement of the

Media. reign of Dejoces to the destruction of Nineveh, 601 B. C., Media may be properly styled a kingdom. From the destruction of Nineveh we may therefore date the rise of the empire of the Medes. Their empire lasted till the taking of Babylon; for we learn from Xenophon, that after the reduction of that city, Cyrus went to the king of the Medes at Ecbatana, and succeeded him in the kingdom. The empire of the Medes had lasted sixty-five years, at the period when the Persian empire took its rise under Cyrus. Passing over the fabulous history of the Medes, we shall begin with the reign of Dejoces, who was chosen by them as their judge, and who, aspiring to the sovereign power, performed that office with the strictest regard to justice. After his resignation of this office, licentiousness prevailed, and it was found necessary to appoint a king; upon which Dejoces was named to the sovereignty, and with universal applause placed upon the throne, 710 B. C. As soon as he had been elected king, and vested with the supreme power, he threw off the mask, and became a tyrant. Ecbatana was built and chosen for the royal residence, and a stately palace was erected for the sovereign. Dejoces, having enacted various laws for the government of the kingdom, and having, in a considerable degree, civilized his unpolished subjects, entertained thoughts of extending the limits of his new kingdom, and with this view he invaded Assyria. Nebuchadonosor, however, at that time king of Assyria, met him in the plain of Ragau, and a battle ensued, in which the Medes were utterly defeated, and Dejoces was slain, after a reign, according to Herodotus, of fifty-three years. The Assyrian king availing himself of his success, reduced several cities of Media, and amongst the rest Ecbatana, which he almost utterly destroyed. Dejoces was succeeded by his son Phraortes, 647 B. C.; and, not satisfied with the kingdom of Media, he invaded Persia, and is said to have brought that nation under subjection to the Medes. Such is the account of Herodotus. Others, however, ascribe the conquest of Persia, not to Phraortes, but to his son and successor Cyaxares. Phraortes, however, subdued several neighbouring nations, and made himself master of almost all Upper Asia, lying between Mount Taurus and the river Halys. Emboldened by his success, he invaded Assyria, subdued a great part of the country, and even laid siege to Nineveh, the metropolis.

On the death of Phraortes, his son Cyaxares was placed on the throne. He was not less valiant and enterprising than his father, and had better success against the Assyrians. With the remains of that army which had been defeated under his father, he not only drove the conquerors out of Media, but obliged Chyniladan to shut himself up in Nineveh. To this place he immediately laid close siege; but was obliged to abandon the enterprise, on account of an irruption of the Scythians into his own country. Cyaxares engaged these new enemies with great resolution, but was utterly defeated; and the conquerors overran not only all Media, but the greater part of Upper Asia, extending their conquests into Syria, and as far as the confines of Egypt. They continued masters of this vast tract of country for twenty-eight years, till at last Media was delivered from their yoke by a general massacre, at the instigation of Cyaxares.

Mediator. The Medes were afterwards engaged with the Lydians; and during the engagement there happened a total eclipse of the sun, which is said to have been foretold by Thales the Milesian. Both parties were terrified, and soon afterwards concluded a peace by the mediation of Labynetus, that is, Nebuchadnezzar, king of Babylon, and Syennesis, king of Cilicia. This peace was confirmed by the marriage of Aryenis, the daughter of Halyattes, and Astyages, the eldest son of Cyaxares; and of this marriage was born in the ensuing year Cyaxares, who, in the book of Daniel (ch. v. 31) is called Darius the Mede. Cyaxares, disengaged from the Lydian war, resumed the siege of Nineveh; and having formed a strict alliance with Nebuchadnezzar, king of Babylon, they joined their forces, and took and destroyed the city (606 B. C.) With this prosperous event commenced the great successes of Nebuchadnezzar and Cyaxares; and thus was laid the foundation of the two collateral empires, as they may be called, of the Medes and Babylonians, which rose upon the ruins of the Assyrian monarchy. After the reduction of Nineveh, the two conquerors led the confederate army against Pharaoh-Necho, king of Egypt, who was defeated near the Euphrates, and compelled to resign what he had formerly taken from the Assyrians. After this victory they reduced all Cœlesyria and Phœnicia; then they invaded and laid waste Samaria, Galilee, and Scythopolis; and at last besieged Jerusalem, and took Jehoiakim prisoner. Nebuchadnezzar afterwards pursued his conquests in the west, and Cyaxares subdued the Assyrian provinces of Armenia, Pontus, and Cappadocia. Again uniting their forces, they reduced Persia and Susiana, and accomplished the conquest of the Assyrian empire. The prophet Ezekiel (ch. xxxii. 22, &c.) enumerates the chief nations who were subdued and slaughtered by the two conquerors Cyaxares and Nebuchadnezzar.

After this victory the Babylonian and Median empires seem to have been united; but upon the death of Nebuchadnezzar, or rather towards the close of his life, a war ensued, which was only extinguished by the dissolution of the Babylonian empire. The Medes, under Astyages the son of Cyaxares I. withstood the power of the Babylonian monarchs, and, under Cyrus and Cyaxares II. utterly destroyed their empire by the taking of Babylon. After the death of Cyaxares, the kingdom fell to Cyrus, by whom the seat of the empire was transferred to Persia.

MEDIASCH, a city of Hungary, in the province of the Siebenbergen, in that part distinguished as the conntry of the Saxons. It is the capital of a circle extending over 268 square miles, and containing about 50,000 inhabitants. The city stands upon the river Great Kokel, is surrounded with walls, and has a Greek, a Lutheran, and a Calvinist church, a Franciscan convent, and 440 houses, with 4235 inhabitants. Long. 24. 16. 55. E. Lat. 46. 8. 31. N.

MEDIATOR, a person who manages or transacts between two parties at variance, in order to reconcile them. The word, in Scripture, is applied, first, to Jesus Christ, who is the only intercessor and peace-maker between God and man (1 Tim. ii. 5); and, secondly, to Moses, who interposed between the Lord and his people, to declare unto them his word (Deut. v. 5, iii. 19).

MEDICAL JURISPRUDENCE.

History.

THE connection between medicine and legislation had been perceived long before it was considered as a peculiar branch of study, or had even obtained a distinctive appellation. Since its importance has been recognized, it is known in Germany, the country in which it took its rise, by the name of STATE MEDICINE; in Italy and in France it is termed LEGAL MEDICINE, and with us it is usually denominated MEDICAL JURISPRUDENCE, or FORENSIC MEDICINE. It is founded on the relations which ought to subsist between human nature and social institutions, and consists in the application of the principles of medical science to the administration of justice, and to the preservation of the public health. Its nature and objects will be best elucidated by a sketch of its progress.

HISTORY OF LEGAL MEDICINE.

Notwithstanding the importance of the objects which it embraces, and their intimate relation to the interests of society, the true origin of Medical Jurisprudence is of comparatively recent date. It is true that traces of its principles may be perceived in very remote times. In the Mosaic institutions the judges are enjoined to consult the *priests*, who were the sole physicians of that age and country, on the modes of distinguishing leprosy from other diseases, on the marks of defloration, and the examination of wounds. In the slight notices handed down to us of the ancient code of Egypt, attributed to Menes, we may observe one trace of the influence of medicine on legislation, in the law which forbade the infliction of corporal punishment on a pregnant female; but among the ancient states of Greece the principles of medical science, though successfully cultivated, seem scarcely to have been applied to legislation, except in certain questions respecting the legitimacy of children, a subject on which the notions even of Aristotle were not very definite. In the writings of Galen, however, we find more distinct traces of legal medicine; as in his various remarks on the difference between the lungs of a fœtus and of an adult, in his treatise on simulated diseases, and in his observations on the legitimacy of seven months' children.

The laws of ancient Rome were borrowed from Greece, and we could scarcely expect to find in them a more refined legislation; but it is worthy of notice, that the laws of the Twelve Tables fix on 300 days as the extreme duration of utero-gestation, the precise term fixed by the Code-Napoleon. Some writers contend that the Roman law authorized the inspection of dead bodies by medical men, because of the twenty-three wounds by which Cæsar fell, the physician Antistius pronounced one only mortal; and because Tacitus has spoken of the marks of poison on the bodies of Germanicus and Agricola: yet we have no proof that such opinions were required by any positive law, or that the judge was in the habit of demanding the assistance of the physician. In the Justinian code, however, we find more obvious traces of the relation between medicine and law; as in the titles *De statu Hominum; De Pœnis et Manumissis; De Sicariis; De Inspiciendo ventre Custodiendoque partu; De Muliere quæ peperit undecimo mense; De Impotentiâ; De Hermaphroditis:* yet in the Justinian code it was not by the testimony of living medical witnesses that such quesions were to be decided, but "on the authority of the learned Hippocrates."

History.

It was chiefly on questions of medical police, as to what regarded the salubrity of cities and stations, that the ancient Greek or Roman magistrates had recourse to medical assistance; and it appears that it was to such subjects that the public functions of the *Archiater* of the lower empire were confined.

Medical Jurisprudence, as a science, cannot date farther back than the 16th century. Various German emperors had in vain attempted the introduction of an uniform criminal code; but George, bishop of Bamberg, in 1507, proclaimed a penal code, drawn up for his states by *Baron Schwartzemberg*, in which the necessity of medical evidence, in certain cases, was recognized: and though this improvement was for some time resisted by the greatest part of Germany, the emperor Charles V. eventually succeeded in persuading the diet of Ratisbon, in 1532, to adopt a uniform code of German penal jurisprudence, founded on that of Bamberg, in which the civil magistrate was, in all cases of doubt or difficulty, enjoined to obtain the evidence of medical witnesses; as in cases of personal injuries, infanticide, murders by poison or other means, pretended pregnancy, simulated diseases, &c. The celebrated *Constitutio Criminalis Carolina* was published in 1553; this must be considered as the true dawn of Legal Medicine, and Germany the country which gave it birth. To the same country must be ascribed the glory of having first thrown the shield of medical science over the victims of a dark fanaticism. The belief in the powers of witches and sorcerers was in full force in the 16th century. It is computed that in Lorrain above 900 persons were burnt alive within 19 years, for the imputed crime of sorcery; and that in the Electorate of Trevers alone, within a few years, 6500 individuals had perished in the flames for the same imaginary crime. In Germany and France instances of pretended demoniacal possession were perpetually occurring; and at Freidberg public prayers were offered up to assuage that dire affliction. Weiher, physician to William, duke of Cleves, had the boldness to impugn these superstitious notions, in a tract published at Basle in 1568, and undertook to prove that witches and demoniacs ought to be considered as unhappy persons subject to hypochondriasis and hysteria, whose maladies should rather excite pity, than render them obnoxious to punishment; while he ridiculed the ordinary modes by which these unfortunate beings were proved to be guilty of the alleged crimes. This attack on a popular superstition aroused alike indignation and vengeance against the daring innovator; and, but for the powerful intercession of his patron, Weiher himself would have perished in the flames, from which he had tried to save others.

In the close of that century many treatises on different branches of Legal Medicine appeared in various countries. Ambrose Paré wrote on monstrous births, on simulated diseases, and a memoir on the art of drawing up medical reports. In 1598 Severin Pineau published at Paris the treatise *De Notis Integritatis et Corruptionis Virginum;* a book still quoted as an authority. The first *system of Legal Medicine* appeared about the same time in Sicily, in the work of Fortunato Fidele *De Relationibus Medicorum;* in which, as might be expected in his age and country, the opinions of the physician are too much warped by his servile deference for the canon law and its clerical expounders.

The rapid progress of anatomy in the commencement

History. of the 17th century now became apparent in the invaluable *Quæstiones Medico-Legales* of Paulo Zacchia, which appeared in successive volumes from 1621 to 1635; a work which will ever be regarded as a landmark in the history of Legal Medicine; and which, by its learning and its sagacious indications, in an age in which chemistry was in its infancy, and physiology very imperfect, places the medical acumen of the great Roman medico-jurist in a very favourable point of view.

The noble discovery of the circulation of the blood gave a new light to physiological reasoning, which was broadly reflected on Legal Medicine: and to Harvey we also owe the idea how the application of Galen's remark, respecting the difference between the adult and the fœtal lungs, might be applied to elucidate cases of infanticide.

About the same time appeared two valuable treatises by Melchior Sebiz, *De Notis Virginitatis*, and *Examen Vulnerum*. In the first he maintained that the existence of the hymen was the real mark of virgin purity; an inference warmly denied by Orazio Augenio and Petro Gassendi: in the second he pointed out the importance of distinguishing between wounds *incidentally* and *necessarily* fatal.

In 1663 Thomas Bartholin, a Danish physician, carefully investigated the period of human utero-gestation, and proposed the *Hydrostatic Test*, or observing whether the lungs of the infant floated or sunk in water, as proving whether it had ever breathed. The rationale of this process was more fully explained by Swammerdam in 1677; but was first applied to practical use by Jan Schreyer in 1682; after having been investigated by Thruston and Rayger.

While these important steps were in progress, Germany set the example of the first public prelections on Medical Jurisprudence. About the middle of the 17th century, Michaelis gave the first course in the university of Leipzig: these were soon followed by the lectures of the celebrated Bohn, who, before the close of the century, had published his valuable works *De Renunciatione Vulnerum, et Dissertationes Medicinæ Forensis*, which were speedily succeeded by the tract *De Officis Medici Duplici, Clinici et Forensis*. The two first were nearly contemporary with the investigations of Welsch and Amman *on the fatality of wounds*, and the celebrated work of Licetus *De Monstris*; and the latter with the valuable *Sepulchretum* of Bonnet.

The mode of conducting medico-legal investigations had attracted attention in France, from the time of Ambrose Paré, through the 17th century. French authors love to trace the rudiments of the science in their country from the 12th century, in the rules given in the *assizes of Jerusalem*, for drawing up exemptions from certain civil and military duties, and in several subsequent ordonnances of their monarchs, for the inspection of wounds: enactments from which we may trace the institution of the *Chirurgiens du Châtelet*. In 1603 Henri IV. authorized his physician to appoint persons, skilled in medicine and surgery, to make judicial inspections and reports in all cities and royal jurisdictions. The difficulty of carrying this into effect induced Louis XIV. to create, in 1692, *hereditary royal physicians and surgeons*, for the same purpose, with various immunities and privileges; but their corruption and venality soon became notorious, and the office was suppressed in 1790.

Various decrees, however, of the parliament of Paris, from the middle to the end of the 17th century, were directed to the improvement of legal medicine; and that body acquired great celebrity by the general equity and good sense of its judgments. Notwithstanding this auspicious commencement, Legal Medicine did not then flourish in France; and the work of Gendry, *Sur les Moyens de bien rapporter à Justice*, shews how imperfect were the then approved modes of investigation; though it proves that the importance of the subject began to be acknowledged. No other French work on Legal Medicine appeared in that century, with the exception of *Doctrine des rapports en Chirurgie* of Blégny, which was superseded in the beginning of the succeeding century by the more useful *L'art de faire des rapports en Chirurgie* of Devaux. History.

The 18th century commenced with happier auspices for our science, and the press teemed with important works on Legal Medicine. As early as 1700 the admirable treatise on the diseases of artificers by Bernardino Rammazzini appeared at Padua. In the following year Valentini published his *Pandectæ Medico-legales*; his *Novellæ* appeared in 1711; and both were incorporated in the excellent *Corpus Juris Medico-legale* in 1722. This work contains a judicious view of all that had been done before him, and is a vast storehouse of medico-legal information.

Several professorships for teaching this subject were about that period founded in the German universities; and the succession of German writers becomes now so numerous that we cannot attempt to give a catalogue, far less to characterize their works. Zittman, Boerner, Kannegeiser, and Teichmeyer, each published systems of various yet acknowledged merit. The *Institutiones Medicinæ Legalis* of the latter long formed the manual of the student: the clear and forcible reasoning of Storch in his work *De Medicinæ Utilitate in Jurisprudentia* (1730), vindicated the high importance of this branch of knowledge: but the *Systema* of Alberti, professor of Legal Medicine at Halle, in six quarto volumes, was the most complete and laborious work ever published on this subject. The writings of this learned man are obscured by his attachment to the mysticism of the Stahlian school; yet the industry with which he has collected facts renders his work a precious mine of information. Curious additions to our knowledge were made by the smaller publications of Loewe, Richter, Budæus, Troppanneger, Fritch, and Wolff, Hermann, Clauder, Herzog, and Parmeon; which are chiefly valuable to those who may be called to exercise the profession in Germany. In the *Bibliothèque Medicale* of Ploucquet will be found the names of those who have dedicated themselves to the illustration of particular branches of this extensive subject; and in the *Collectio Opusculorum* of Schlegel will be found some of the best detached treatises of the first three-fourths of the last century on the subject of wounds, poisoning, infanticide, utero-gestation, insanity, and the legal inspection of dead bodies. About the same time appeared the *Anthropologia Forensis* of Hebenstreit, the *Specimena* of Fursteneau, the *Institutiones* of Ludwig, and the *Elementa* of Fazelius. The lectures of Haller belong to this same period, though they were not published till 1781–2. Towards the close of the last century, the Germans were almost the only successful cultivators of Medical Jurisprudence. The *Elementa* of Plenck appeared in 1781, and the book is still considered a good introduction to the study. The *Bibliothek* of Daniel appeared in 1784; and in it we find the name of *state medicine* given to this branch of knowledge. Between 1790 and 1800, appeared the *Conspectus* of Sikora, the *Handbuch* of Loder, the *System* of Metzger, and the *Entwurf* of Müller.

During the last century little was done in Italy after the time of Rammazzini; and in France the subject had attracted little attention, until the celebrated case of Villeblanche called forth the memoir of Louis on the period of utero-gestation, in which he attacked the pretended instances of protracted pregnancy with powerful arguments, which were seconded by Astruc and Bouvart, but vehemently opposed by Le Bas and Antoine Petit. This controversy gave rise to many able publications, in which Pouteau and Vogel took part; but victory remained with Louis and his adherents.

Louis wrote also a valuable memoir on the anatomical examination of bodies found hanged; he pointed out the mode by which we are able to distinguish assassination from suicide in such circumstances. He applied them to the

History. celebrated cases of Calas, of Syrven, Montbaillet, and Baronet, in which are models of medico-legal investigation; and he may be considered as the first who publicly taught in France the just application of medical knowledge to jurisprudence.

The subject of poisoning was examined by Sallin, in a case where a person had been buried sixty-seven days; and he made a very ingenious attempt to investigate the effects of poisons; but has sometimes substituted speculation for facts.

In 1789 professor Chaussier read his excellent *Memoire* before the Academy of Dijon; in which he shewed the necessity of careful inspection by the medical witness in all cases of death from blows or wounds, and gave admirable models of medico-legal reports. Next year he delivered a course of lectures on Legal Medicine to numerous pupils. The last year but one of the last century gave to the world the very excellent *Traité de Medecine Legale* of Foderé.

It may excite surprise that in this sketch we have made no mention of British authors. The fact is, that with the exception of the short Elements of Medical Jurisprudence published by Dr. Samuel Farr in 1788, which is little else but an abridgement of Fazelius, there was no treatise on Forensic Medicine in the English language.

It is true that some medico-legal questions are ably but incidentally treated in the writings of Mead, Monro, Denman, Percival, and John Hunter, and that an interesting Essay was published by Dr. Wm. Hunter "On the uncertainty of the signs of murder in the case of bastard children;" but the importance of the study, as a whole, was not understood in this country till long after the publication of many valuable systems in Germany, Italy, and France.

In the present century France took the lead. The end of the last century was marked by the institution of three professorships of Forensic Medicine. Mahon was the first French professor, and his reputation as a teacher gave him a name, which the posthumous publication of his lectures has not sustained. The short *Cours de Medicine Legale* of Belloc appeared in 1802. Tartra's excellent Essay on *Poisoning by Nitric Acid* was published in the same year, between which and the year 1810 various short treatises appeared, chiefly on detached branches by Achart, Drouard, Lavort, Masson, Faulaure, Desortieux, Vigné, Lamarre, Banc-Cavé, Godemar, Raffenaut, De Lisle, and Faure.

In 1814 appeared the important *Toxicologie* of Orfila, (a Spaniard naturalized in France), which has changed the face of this part of Medical Jurisprudence, by the number of experiments, the original views on the nature and action of poisons, and the disquisitions on the modes of detecting them, it contains. The French practitioner may consult with advantage the *Manuel* of Bertrand, published in 1817; and the admirable *La Medecine Legale relative à l'art des Accouchemens* of Capuron, has scarcely left us any thing to desire on this branch of the subject. In 1819 appeared the excellent Essays of Lecieux on *Infanticide*, of Renard on *Medico-legal examinations of dead bodies*, of Laisne on *Perforations of the Stomach*, and of Rieux on *Ecchymosis*, *Suggillation* and *Contusion*, in the same volume. Valuable detached essays by Foderé and Marc are contained in the *Dictionnaire des Sciences Medicales:* and we may close our French list with the *Manuel* of Briand and Brosson, republished in 1828; the *Secours à donner aux Asphyxiées* of Orfila, which appeared in 1833; and the useful *Manuel Complet* of Sedillot.

During the present century Germany has not been idle. We have good compends by Schmidmüller, Masius, and Willberg. Rose published a very valuable essay on *Medico-legal Dissection*, which has been translated and enlarged by Marc, (Paris, 1808); and an excellent treatise on *Pharmaco-chemico-Medical Police*, was given to the world by Remer. This last treatise has been translated into French by Lagrange and Vogel, in 1816. Among many works which have appeared in Germany of later years, connected with our subject, we may mention the curious collection of cases by Von Fuerbach, published in 1828, entitled *Merkwürdiger Berbreehen*—Remarkable Crimes; the little tract of Drs. Bunsen and Berthold, on the power of *Hydrated Peroxide of Iron as an antidote for Arsenic*, which appeared at Göttengen in 1834; the *Contributions to Legal Medicine* of Bernt; and the masterly analysis of various poisons, by Buchner and Herberger. History.

Only two medico-legal works of any consequence have proceeded from the press of Italy within the present century: the *Instituzione di Medicina Legale*, by Tortosa of Vicenza, and the *Medicina Legale* of Barzellotti.

Medical Jurisprudence may fairly be said to have only commenced in Britain within the present century. The first lectures ever delivered in Britain were given in the University of Edinburgh, in 1801, by the elder Dr. Duncan; and the first established Professorship was conferred by government on his son in 1803, since which period it has been regularly taught in that seminary.

The first original British work on Medical Jurisprudence was Dr Male's *Epitome of Juridical or Forensic Medicine, for the use of Medical Men, Coroners, and Barristers*, which appeared in 1816; and, though a short sketch, it contains interesting notices of English cases, and English law. *Medical Jurisprudence, as it relates to Insanity, according to the Law of England*, was published, in 1818, by Dr Haslam, in a little volume, illustrated by original cases. But the most valuable work then presented to the public, in an English dress, was the *Principles of Forensic Medicine* of Dr Gordon Smith; a volume commendable as an elementary treatise, less diffuse than most of the continental systems, and interesting to the British practitioner, by the numerous references to British cases and to our national codes. In 1820 Dr. William Hutchinson published his useful dissertation *on Infanticide*, in which its relation to physiology and Jurisprudence is very ably considered. These works were soon followed by the more costly publication of Paris and Fonblanque, in three octavo volumes; in which, among some matter little interesting to the general student, are important references to English Jurisprudence.

The last British work we shall mention is the admirable *Toxicology* of Professor Christison, which appeared first in 1829, and has since gone through a second and a third edition; a work the most philosophical and perfect which has yet appeared on the subject of poisons.

It would be improper to pass over the labours of our trans-atlantic brethren in this branch of science. In 1819 Dr Cooper of Philadelphia republished in America the treatises of Farr, Male, and Haslam, with *the remarks* of Mr Dease, intended for the information of juries and young surgeons; a letter originally addressed "to the Chief Justice of Ireland, by a surgeon of that country." Dr Cooper added some notes, and a good digest of the laws relating to insanity and nuisance, for which his former station as a judge in the American courts well qualified him. Four years afterwards the American press presented us with the excellent work of Dr. Beck, which is a compend of all known on the subject. The author has freely availed himself of the writings of his predecessors, in many instances of their expressions and trains of reasoning; but his references to original authorities are copious and correct; and we must consider the last edition, recently brought to this country, as the best work, on the general subject, which has appeared in the English language.

Forensic Medicine.

Medical Jurisprudence may be divided into two great branches, *Forensic Medicine*, and *Medical Police*. The first may be conveniently subdivided into, 1st, Questions affecting the civil rights, or social duties of individuals; 2d, Injuries to Property; 3d, Injuries to the person. The second part may also be subdivided into, 1st, Questions affecting the preservation of individuals; 2d, What relates to the health of men collected into communities.

It is obviously impossible, in the limits of a dissertation of this nature, to do much more than allude in general terms to most of the subjects included under these branches.

PART I.—FORENSIC MEDICINE.

SECTION I.—QUESTIONS AFFECTING THE CIVIL OR SOCIAL RIGHTS OF INDIVIDUALS.

Development of the Body.

I.—Development of the Human Frame.—The usual development of the corporeal and mental powers becomes of high importance in establishing personal identity, in determining criminal responsibility, and in giving validity to various civil contracts.

1. *Infancy* is the period from birth until the completion of the seventh year; and its progress is best determined by attention to the size of the body, the evolution of its proportions, and the state of the first teeth. Its conclusion is marked by the loss of the milk incisors, and coming of the first permanent teeth.

2. *Childhood* may be considered as extending from the last period to the 14th or 15th year, or the commencement of puberty. The expansion of the body, the state of the teeth, and of the genitals, are its principal characteristics.

3. *Adolescence* is marked by changes in the whole constitution, by the commencement of the beard in males, and of the catamenia in females; this is of uncertain duration, but may be considered, with us, as extending to the 17th or 18th year.

4. *Youth* is the period between adolescence and the full perfection of the bodily powers. In it the generative function is perfected. We may consider it as terminating with the age of legal majority, though probably it should be extended to the 25th year, as it is with some nations.

5. *Virility* is that period during which all the bodily powers are perfect, and the mental faculties are matured. It has no definite bounds in man; but the perfection of the bodily powers of the female may be considered as bounded by the time when the catamenia cease, or woman is incapable of being a mother. That period is usually about her 45th year. It is during this period that all the bodily and mental faculties have generally acquired their full perfection in both sexes.

6. *Old Age* has no absolute beginning, fixed by nature, except in what we have just noticed of the female. It is exceedingly difficult to ascertain the age of persons of either sex in this period of life, so that no general rule can be fixed, and the limits of old age on either hand cannot be determined. Its general characteristics are stiffness of the limbs, wrinkling of the skin, loss of teeth, blanching of the hair, impaired vision, and decay of all the bodily faculties. Its approaches are often marked by the appearance of fan-like wrinkles at the outer canthus of the eye, by increased obesity, and by the shoulders becoming round.

7. *Decrepitude* is the last stage of human existence, in which the bodily vigour is decayed; the knees and spine are curved, from the inability of the muscles to support the weight of the superior parts of the body, or by alterations in the form of the cartilages; the senses are blunted; and the only refuge is the grave. The periods at which these various changes take place are accelerated and retarded by constitution, climate, food, habits, education, and occupation.

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Duration of Life.

II.—Duration of Human Life.—The ordinary chances of human life are an important subject of inquiry, deduced from accurate comparisons of registers of births and deaths. On this is founded the system of annuities, the principles of benefit societies, and of insurances on lives. Unfortunately these registers have been so ill kept in Britain, that our own tables have generally been calculated from foreign registers, especially those of Sweden and Finland. It is well known that Dr Price's calculations, from the Northampton tables, gave far too high a rate of mortality; and have caused much loss to the nation, in the payment of public annuitants. The later tables, calculated from the last Swedish and Carlisle registers, have proved this most decisively; and the labours of Messrs. Milne, Lyon, and Finlaison have since furnished us with surer data for our calculations of probabilities of survivorship, and the payment of benefit clubs. The important questions connected with this subject, and the light which a better system of registration is capable of throwing on many subjects connected with population, and the progress of medical knowledge, the important civil rights of individuals involved in the accuracy of registers of births, marriages, and deaths, should induce the government to take up the whole question of registration, and place it on a public and permanent footing.

Personal Identity.

III.—Personal Identity.—To those little familiar with such inquiries, the danger of mistaking one person for another will not appear very considerable; but the fatal errors which have arisen from this source are too well known in the jurisprudence of every country. It becomes, therefore, of consequence to point out the circumstances by which personal identity may be rendered doubtful, and to indicate the marks by which it is best established. The first may include the effects of age, climate, aliment, habits, passions, wounds, diseases, &c. The circumstances which chiefly enable us to identify one long absent from his native country are, accurate observation of his likeness to his family; his resemblance to what he once was; in some instances his dialect; his recollection of past events; but, above all, the occurrence of scars, or *nævi materni*, known to have been on the individual in question.

Marriage.

IV.—Marriage.—Under this head the principal business of the medical jurist is with the nubile age, according to nature, and legislative enactments; and with physical circumstances affecting the legality of marriages, which may justify divorce.

1. The nubile age, with us, is not below fourteen for the male, and twelve for the female, that being the ordinary period of puberty in our climate; but young persons may after this age be prevented from marrying till the age of majority, by parents and guardians, in England, though this seems doubtful in Scotland.

2. The physical circumstances which may invalidate a marriage are, lunacy in either of the parties at the time, and physical inability to consummate. There are instances of this last being pleaded and sustained in our Courts. Certain diseases, such as epilepsy, are held in some countries to invalidate marriage, but not with us.

Impotence.

V.—Impotence and Sterility may arise from,

1. *Functional Causes.*—Of these, habitual intoxication, excessive venery, and diseases which greatly debilitate, or affect the common sensarium, are the chief. They are generally temporary only. In females the same causes may produce sterility; to which may be added excessive leucorrhœa, dysmenorrhœa, anaphrodisia, &c.

2. *The Organic Causes* are malformation of the genitals in both sexes, or total deficiency of some of them. We must be careful, however, not to infer the want of testes,

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because none are found in the scrotum. In some individuals they have remained through life in the abdomen, as occurs in the unripe fœtus.

Pregnancy.

VI.—PREGNANCY presents a wide field for medico-legal evidence.

1. *The limits* between which it is possible, belong to the province of the medical jurist. It may be limited to the period during which the catamenia recur; but this varies from under ten to more than fifty years of age. A few remarkable instances of impregnation after sixty are recorded; and instances of very early puberty also have occurred, even so early as about four years; but these are exceptions to a general rule, which should be kept in mind, in judging of imputed pregnancy.

2. *The signs* of true pregnancy should be impressed on the mind of the jurist; for he may be called to determine whether a capital sentence is to be suspended on this plea, or whether an accusation of pregnancy may not, from the effect of disease, be made against a virtuous female. It is in the early months that the principal risk of error lies. The usual signs are, the cessation of the catamenia, the darkening of the areola round the nipple, the general state of the breasts, the state of the os uteri, the form of the womb as felt over the pubes; and as the pregnancy advances, the tumefaction of the abdomen, and the motions of the fœtus. At this period, the stethoscope, applied to the abdomen, affords a certain indication. The female, for this last examination, should be in bed, lying on her back, with a sheet drawn smoothly over the abdomen: place the stethoscope between the navel and the pubes, and an attentive ear will readily distinguish two sounds; a *whirring* one, synchronous with the maternal pulse; and the pulsations of the fœtal heart, considerably quicker and of a sharper tone.

3. *Limits of Utero-gestation.* Pregnancy may be protracted beyond nine months, or forty weeks, its usual term; but not so considerably as was once imagined. The Justinian and some modern codes were very indulgent in this respect. Ten kalendar months, or three hundred days, is the extreme limit allowed by the present French code; the Prussian extends it to three hundred and two days, a period sufficient to include every case of protracted pregnancy. The law of England at present has no definite limit; but a case beyond the usual term would go to a jury. The difficulty of any female ascertaining the precise period of her conception is the cause of the discrepant opinions of the physiologists on this subject.

Parturition

VII. PARTURITION. This subject is also one of great delicacy, and involves several questions.

1. *Whether it be approaching* in general, may be known by indications described in all books on midwifery. The steps of natural, protracted, and preternatural labour should be familiar.

2. *But the signs of recent delivery* are more important to the jurist. These are, the bruised state of the genitals, relaxation of the vagina and of the uterus, the presence of the lochial discharge, the general appearance of the female, and the formation of milk in her breasts.

3. *The viability* of the child is very important, and is recognized by the perfection of its organs, the position of the *median line*, the appearance of its nails, and skin, the cry of the infant, and its capability of sucking. This is a subject of interest; because in some instances, if a child be born *not viable*, it may affect the succession to property, when the mother dies in childbed; and it may bear on certain cases of alleged infanticide. One other question connected with this subject is, when there is a considerable interval between the birth of twins, whether these are to be considered as conceived at the same time. Many deny the possibility of *superfœtation*, which in such cases is contended for by others; but it is a subject involved in much obscurity.

Forensic Medicine. Monsters.

VIII. MONSTERS AND HERMAPHRODITES. No living human birth, however much it differ from human shape, can be destroyed without committing a capital crime. The law states that *monsters* cannot inherit; but it has left us in the dark, as to what should be considered sufficient deviation from the human form to constitute a monster. *Hermaphrodites* are now considered as beings with malformations of the organs of either sex: and physiology does not admit the existence of true hermaphrodites with duplex perfect organs.

Paternity.

IX. PATERNITY AND AFFILIATION become medico-legal questions when a considerable interval has elapsed between the birth of a child and the death or absence of its reputed father: ten kalendar months being the utmost limit to which modern physiology would extend the period of utero-gestation. This subject involves questions respecting children born during a second wedlock of the mother, the circumstances of posthumous children, the laws of bastardy, and the mode of treating alleged cases of suppositious children.

Presumptions of Survivorship.

X. PRESUMPTIONS OF SURVIVORSHIP.

1. *When a mother and her new-born infant are found dead*, important civil rights depend on the question, which lived the longest; as the husband's right to be *tenant to the curtesy*, or the descent of property derived *from the mother*. The law of England in such cases admits such slender proofs of life in the fœtus as would not be received elsewhere, and leaves much to the evidence of a medical witness. Elsewhere the child must either cry or look around, to constitute a quick birth; but in England a quiver of the lips has been received as a proof of life, in defiance of physiology.

2. *When two or more persons perish by a common accident*, without any but probable means of ascertaining who perished first, as in cases of shipwreck, or on a field of battle, the descent of property may become the subject of dispute. Such questions have been rarely decided in Britain; but probably should be determined on the principles laid down in ancient Roman law, or in the Code-Napoleon.

Mental Alienation.

XI. MENTAL ALIENATION. This interesting subject presents a wide field for speculation to the medical jurist.

1. He should be familiar with the four forms of insanity, *Mania*, *Monomania*, *Dementia*, and *Amentia*, and be able to indicate the leading symptoms and the most judicious treatment of each. He should be able to detect feigned cases of insanity, and to prevent real lunatics from being treated as criminals.

2. *The chief questions* that may fall under his decision are, how to distinguish the disease, and to prove a man insane; if there be a real lucid interval; what period of life is most liable to insanity; what diseases are most liable to be confounded with it; whether it has increased in these kingdoms.

3. *The nature and management of Lunatic hospitals* are also in his province. It must never be forgotten, that, in such establishments, no more restraint should be employed than is necessary to prevent the unfortunate being from hurting himself or others: while the order and economy of the house is to be maintained by a mild but firm administration; rather like the authority of a parent over children, than the rigid severity of a task-master towards a dependant.

Rights of Deaf and Dumb.

XII. THE RIGHTS OF THE DEAF AND DUMB are secured by law; and if the intellect be perfectly sound, there is now no question of their perfect competence to enjoy all the civil rights of other subjects of the state. They can intimate legal consent by signs, or by writing; and should be considered as responsible agents.

Maladies Exempting from Public Duties

XIII. MALADIES EXEMPTING FROM PUBLIC DUTIES belong to the medical man, both in his civil and military capacity. He may be called to decide whether a man be fit,

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without imminent injury to his health, or danger to his life, to perform the duties of a juryman, of an officer of justice, or to serve in the navy or the army. In all such cases the certificate of health must be carefully drawn up, on an honest consideration of each case, and a fearless determination to do justice.

Simulated Diseases.

XIV. SIMULATED DISEASES present a field of investigation, requiring caution and discrimination. It may be the duty of the medical man to aid the magistrate in the detection of the guilty impostor, or the military tribunal in consigning to merited punishment the pretended invalid. No questions require more professional skill, more self-possession, or more knowledge of human character.

SECTION II.—INJURIES TO PROPERTY.

Nuisances.

I. NUISANCES FROM MANUFACTORIES, &c. These may affect the property of our neighbour in different ways; or the nuisance may be a public one. The first is what is termed a private nuisance, and may be abated by an action for damages; the second is a common or public nuisance, and the proper remedy is by indictment. In certain cases the injunction of a court of equity will stay the nuisance in a summary manner.

It was at one time ruled, "that usefulness shall compensate for noisesomness, and that unless it could be proved *deleterious* to the health, a manufacture, however disagreeable, might be introduced into a town:" but by several later decisions of our judges, it is sufficient to prove that the nuisance complained of is very disagreeable, and renders the property of a neighbour less valuable, or diminishes in a marked degree the comfort of his life. In judging of such cases, a medical man is often on delicate ground, between parties deeply interested in the issue of the cause: but we may in general terms conclude, that what is very disagreeable to the olfactory organs of most persons is injurious to health; and now it is sufficient to prove the very offensive nature of the nuisance, to obtain its abatement or suppression.

The principal nuisances which are likely to become the subjects of an action are:

1. Establishments or manufactures in which offensive odours are either naturally given out, or generated by *putrefaction*,—such as the erection of privies, piggeries, cattle-pens, slaughter-houses, cemeteries, collections of decaying animal and vegetable substances, steeping of hemp and flax, starch making, dealing in various animal matters, as in the trades of the *knacker* and *gut-spinner*.

2. Manufactures which evolve noxious or offensive effluvia by the *aid of heat*,—as in sugar refining, dyeing, glue-making, hartshorn and ivory-black works, Prussian blue making, rendering of fat and tallow, boiling of whale and fish oil, leaf-horn manufactories, varnish making, soap works, acid making, alkali works, preparation of chlorine, smelting houses, coal-gas works, turpentine making, unconsumed smoke from steam-boilers, &c.

3. Manufactures which *corrupt or pollute streams or springs*,—as bleaching, dyeing, tanning, gas making, lime-burning, and the like.

4. Establishments that become nuisances from their *noises*—as the business of the tin-plate worker, the copper-smith, the trunk-maker, the boiler-maker, *tilting* machinery, &c.

Arson.

II. ARSON. The crime of wilful fire-raising can rarely become the subject of medico-legal investigation, except when there is a doubt whether the alleged fire may have arisen from spontaneous combustion. Spontaneous combustion may arise in inert matter from

1. *Friction or percussion*, by which the latent heat of bodies is suddenly converted into sensible heat.

2. *By fermentation* of vegetable matter,—as in the firing of new hay, of collections of linen rags, roasted bran, and powdered charcoal; in which the heat excited appears to be owing to the rapid absorption of watery vapour, which, when condensed, gives out its latent caloric in sufficient quantity to cause ignition.

3. *By chemical action*,—as in the effect of drying oils on hemp, flax, cotton, and on some powders,—as that of charcoal, and black oxide of manganese; the action of nitric acid on essential oils, indigo, &c., or the mixture of oil with wool. Under this head also may be advantageously discussed the singular combustions of the human body, which have sometimes led to accusations of murder, when the event was due to spontaneous changes in the living body.

Forgery.

III.—FORGERY AND FALSIFICATION OF DOCUMENTS.—This may be of two kinds:

1. *Forgery of Engraved or Printed Bills.*—The importance of preventing forgeries, in a great commercial country, where public and private bills form an immense portion of the circulating medium, has given rise to various contrivances for the prevention of frauds. This has been attempted by introducing peculiarities in the manufacture of the paper, as the use of *water marks*, and colouring the pulp; but ingenious knaves have imitated both successfully. It has been also attempted by employing complicated designs, not easy of imitation. The most ingenious and successful effort of this kind is the multiplication of the same design, by Mr. Perkins's machinery, through which the *same figure* cut on steel afterwards hardened, may be indefinitely multiplied, by being transferred to copper. The success of this method is proved by the very few forgeries which have taken place on the banks which have employed his plates. Substitution of one sum for another has sometimes been made. This is easiest prevented by the multiplication of the word or figures on the face of the note, and also by care in the manufacture of the printing-ink. It is found that an ink composed of lamp-black, Prussian blue or smalt, with copal varnish, is more difficult of erasure than common printer's ink.

2. *Falsification of Deeds*, and forgeries of names, have been committed by the erasure of the common ink used in the signatures. Common ink is usually effaced by diluted nitric, or oxalic acids, by solutions of chlorine, by caustic alkalis, and by butter of antimony. All these substances soften or injure the texture of the paper, but the traces of this injury have been effaced by washing, sizing, and pressing the paper. If these steps have not been carefully performed, however, the writing may, in some instances, be restored; the erasure by acids, in that case, becomes manifest on the application of an alkali—the effect of alkalis by acids; but chlorine may leave no trace of its employment, except the extreme whiteness of the paper. In deeds and writings of importance the best preventive would be to use as an ink a solution of copal in oil of lavender, coloured by lamp-black. The defect of this ink is, that it is apt to become thick, and not to flow freely from the pen; but it cannot be erased by the means already noticed.

Coining.

IV.—COINING OF FALSE MONEY.—The care with which the die is prepared will not always secure against frauds of this sort, as the coin itself offers a ready means of obtaining a mould, of sufficient sharpness for the purpose of the coiner. The object of such persons is to pass off base alloys for pieces of gold and silver. These may be detected by deficient specific gravity; but, in the ordinary business of life, this is not a practicable test. Most of the base alloys are much less sonorous than the precious metals, and the sound is therefore employed to ascertain the genuine coin. All coin is alloyed with copper, which imparts hardness, and prevents loss in *wearing:* this quantity, in our mint, amounts to two parts of alloy for every twenty-two of pure gold or

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silver, or 1-12th. The simplest method of detecting the intermixture of too large a quantity of alloy is by the change of colour produced when a streak is made on *touchstone*, and compared with the streak formed by needles of metal of ascertained purity; but chemical examination is to be preferred.

1. *Debasement of Gold* is ascertained by dissolving a given weight of the alloy, cut into small pieces, in pure nitric acid. This will leave the gold, but dissolve the baser metals; and the weight of the residue, washed and dried, gives the quantity of gold present. The nature of the alloy may be found by different chemical tests. There is only one debasement of gold coin not to be thus detected. Gold coin has been debased by platinum. If the attempt be made to form an alloy, it spoils the colour of the gold; but at Rouen it was accomplished by plating the platinum with gold so nicely, as to give the piece its due weight. Cutting such a coin will detect the fraud. If an alloy has been made, it may be detected by the colour being greyish, or by dissolving the whole in nitro-muriatic acid; when the addition of muriate of potassa, or of ammonia, to the acid solution, throws down a yellow precipitate, if platinum be present.

2. *Debasement of Silver* is usually detected by *cupellation*. The weight of the button of silver left on the cupel gives the quantity of silver in the alloy. It may also be found by dissolving the alloy in nitric acid, and precipitating the solution by muriate of soda: the precipitate blackens by light, and affords the means of ascertaining the quantity of silver in the compound.

SECT. III.—INJURIES AGAINST THE PERSON.

These may be A, such as do not imply the loss of life; or B, such as usually endanger or destroy life.

A.

Defloration

I.—Defloration.—The signs of defloration are obscure. The state of the sexual organs have been chiefly relied on as indications of the loss of virginity, and in particular the rupture of the hymen; but the hymen has been found entire in some females who have had carnal intercourse with man, and is sometimes naturally wanting, or may be destroyed by disease. The appearance of the nymphæ, and the size of the vaginal orifice, are not certain indications, any more than the appearance of the carunculæ mystiformes, or the firmness of the mammæ. It is only by considering all the signs together, that we can arrive at any just conclusion.

Rape.

II.—Rape.—This crime consists in the forcible knowledge of a woman against her will; her resistance must be continued to the utmost, while she retains her senses or the power of struggling with the ravisher, unless she may have yielded to the immediate fear of death. It is not a *rape*, without these conditions being complete; the woman otherwise is supposed to have consented to the act, which may indeed have commenced in violence, but have terminated with her consent. An *infant*, however, under ten years of age, cannot give legal consent; and whoever has carnal knowledge of such an infant, either with or without her consent, is guilty of a capital crime. The proofs of rape, besides the consistency of the woman's story, mainly depend on the marks of violence on her person. If a virgin hath been violated, the injury to the sexual organs, with the precautions mentioned under defloration, will be taken into consideration. If a married female be the victim, we must look for bruizes on her own person, or injuries she may have inflicted on the ravisher during her resistance, which last are accessory proofs of no small importance. The crime may even be perpetrated on a prostitute. It is rape, if the act be forcible, and against her will. The slightest penetration is sufficient; emission is not now required to be proved. The physical signs of rape soon pass away; and unless the female be inspected within ten days after the alleged violence, we shall, in most cases, vainly seek for confirmation of the allegation from inspection. The charge of rape is not invalidated by the female conceiving, nor by the occurrence of syphilis in the woman.

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III.—Mutilation.—*Demembration*, mutilation of the face, cutting or maiming, are capital crimes by Lord Ellenborough's act. The extent of the injury may often be referred to a medical man; and in a case of *slitting the nose*, an English judge overruled the objection of the prisoner's counsel, "that the nose was only *cut*," by stating, "the surgeon sware it was *slit*;" and that slit was anciently synonymous with cut. Castration was always, in Britain, considered as a capital offence, even when other *mayhems* (as mutilations are termed in English law) were punished by fine and imprisonment. In France, the perpetrator is condemned to hard labour for life, except where it has been "immediately provoked by an outrage against modesty." Castration, long after the infliction, may be recognised by the cicatrix of the wound.

Mutilation.

B.

Criminal Abortion.

IV.—Criminal Abortion.—The laws of Britain recognize this crime only after the period of *quickening*, on the false idea that then only life enters into the fœtus. Quickening is merely the mechanical escape of the gravid uterus from the pelvis into the abdomen, and usually takes place in the fourth month of utero-gestation. Before this has taken place, causing a woman to abort is not a crime in our code, though it be so in that of some other countries, as in France; and ought to be so; for quickening has nothing to do with the life of the fœtus, which has been a living being long before. The chief means by which abortion is sought to be accomplished are, by blows and bruises on the abdomen, by the administration of drastic purgatives, or other medicines acting violently on the human frame, by repeated venesection, and by the introduction of pointed instruments into the womb. None of the means, except the last, are certain in their operation, but all are highly dangerous to the mother; and one who only essays abortion may thus commit a double murder. In cases of alleged abortion, the medical witness has to consider the involuntary causes which may produce it; as accidental falls and blows, strong mental emotions, errors of diet and regimen, or spasmodic diseases; and he should balance these against the marks of premeditated design.

Infanticide.

V.—Infanticide.—By the laws of Britain, the mother who concealed her pregnancy till she was delivered of a dead child, or who, during labour, failed to cry out for assistance, or whose infant disappeared after birth, was formerly held guilty of infanticide; and many convictions and executions took place on this cruel statute. In later times very moderate proof of these three circumstances was held sufficient to invalidate the capital charge. Even in England, in cases of the murder of bastard children, contrary to all the usual forms of justice, a statute of James I. threw the *onus* of proving her innocence on the mother; and it was not until the 43d year of George III. that this iniquitous law was repealed, and the same rules of evidence here applied as in other cases of murder.

This subject involves some very nice points of legal medicine. The proofs of the child being born alive enter into the case. It must be proved to have arrived at the period when there was a probability of its living; its body should be carefully inspected for marks of wounds or bruises; its cavities should be opened, lest there be traces

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of injuries sufficient to have caused death, found in the head, abdomen, or chest; the state of the peculiarities in the fœtal circulation, and of the organs of respiration, must be examined; and we must observe whether the lungs seem to have been dilated by breathing, or remain in the dense condition and backward position they have before respiration has commenced. This leads us to consider the celebrated *docimasia pulmonum*, or test by their sinking or floating in water, which was at one time regarded as indisputable proof of the death of the child, before or after birth, but has now been considered as ambiguous. If, however, we try the lungs together with the heart, with that organ separated, each lung separately, and also detached portions of the lungs, we shall generally find little difficulty in deciding the important question, especially if attention be paid to the quantity of blood in the lungs, and the state of the *ductus venosus* and *d. arteriosus*, the contents of the air-tubes, and of the alimentary canal. We must carefully distinguish between the effects of artificial insufflation of the lungs after death, and their floating from respiration, or from incipient putrefaction. In cases of artificial insufflation, the whole lungs will not float, and the air may be squeezed out of a cut portion of the lungs, so as to sink in water; whereas, it is not possible, by compression with the thumb and finger, so to free from air a portion of lung that has respired, that it will not float. Putrefaction may be distinguished by the smell, and the air not being in the cells, but in oblong globules in the cellular tissue uniting the cells.

Infanticide from strangulation, from drowning, and from mephitic air, may be distinguished by the marks to be mentioned under *asphyxia*. Infanticide may be produced by *omission*, as by neglecting to tie the navel string; in which case the body will appear bloodless, the great vessels near the heart, and that organ itself will be empty. The child may perish, if not removed from the discharges which accompany delivery; and the possibility of this happening, without any fault of the mother, must be taken into consideration. The infant may die from exposure to cold. If it be found in a remote or sequestered situation, that would be ground for suspicion. If there be meconium discharged from its bowels; if it exhibit marks of starvation, in the emptiness of its alimentary canal; or if it appear to have been fed, we may be sure that it was born alive, and probably perished from criminal neglect. Any artificial objects, such as articles of dress, found near the child, should be carefully preserved, as one means of identifying the exposer; and if foot-marks are seen there, they should be accurately measured and noted.

In cases of exposed infants, it is very important to ascertain the real mother. As such exposure usually takes place soon after birth, comparing the age of the infant with the signs of recent delivery on the suspected mother, is the best method of proving the connection between them.

Homicide.

VI.—Homicide.—It is only with culpable homicide, and with murder, that the medical jurist has to deal. When a person is found apparently dead, a medical man may be required to inspect and report on the cause of death. He should, of course, first ascertain whether it be a case of real or only of apparent death. This sometimes is not easy. Singular instances of resuscitation from apparent death are noticed by Winslow, Bruhier, and others, which should make us pause ere we hastily pronounce a person dead, without evident causes for his death appearing on his body. Neither pallor of the face and lips, insensibility to stimuli, cessation of the organs of respiration and circulation, loss of heat, nor even stiffness of the limbs, are infallible criteria. Until, along with these, we have marks of incipient putrefaction or decomposition, we cannot be absolutely certain that a person is quite dead; and, in all cases of doubt, we should wait for incipient putrefaction ere we sanction interment. Where the symptoms appear at all equivocal, we should scarify, or apply hot oil to some parts of the skin.

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Here it may be proper to describe the general method of carrying on the *medico-legal* examination of a body.

In cases where a person is found dead, the body should be carefully inspected for external wounds or marks of contusions. Any wound, however minute, should be traced with a probe, and followed to its termination by the knife. Blackish marks should be cut into, in order to ascertain whether they be the effect of the effusion of coagulated blood, or merely the consequences of that infiltration of the skin which takes place in the depending parts of bodies after death. The first is termed *ecchymosis;* the latter may be distinguished from the former by the name of *sugillation*. In the subsequent examination of the head, the hair should be removed, the scalp inspected, and afterwards divided from ear to ear, over the vertex; the skull-cap removed; the state of the brain and its membranes carefully marked, and especially any unusual appearances noted down. All should, on the spot, be committed to writing —nothing trusted to the memory, however tenacious. The inspection of the larynx, trachea, and gullet, is best performed by making a cut through the lower lip, and down the fore part of the neck and chest, to the xiphoid cartilage. Transverse cuts should then be extended from the longitudinal one, along the edges of the lower jaw and the collar bones, so as to enable us to turn back the integuments of the neck. The symphysis of the chin should then be sawed through, and the soft parts divided. We can thus separate the two sides of the lower jaw. When the tongue is pulled forward, the fauces, and upper part of the œsophagus and larynx, are freely exposed, and the introduction of acrid poisons, or of foreign bodies, may often be thus detected. The state of the cartilages of the larynx and trachea should be noted, as fracture or displacement of these has occasionally detected strangulation. A ligature should be put on the lower part of the gullet, and the tube divided above the ligature.

The abdomen may next be opened, by a cut through the skin from the sternum to the pubes. In new-born infants the whole skin and abdominal muscles may at once be cut through, along the cartilages of the ribs on each side, and thence to the anterior edge of the ileum, curving downward to the pubes. This will, when the flap thus formed is turned down, expose the abdominal viscera sufficiently, without disturbing the vessels of the umbilical cord. In the adult, we may first separate the skin of the abdomen from the muscles, in one line from the sternum to the pubes, and, as it is easily extensile, cut out a flap of the muscles of the abdomen, as above directed, so as to expose the viscera. The skin so divided makes a neater appearance when sewed up, than when the muscles and skin are divided together, as in the infant. A ligature should be put on the duodenum, and division of the intestines made below the ligature; so that we may remove the stomach and its contents, and reserve them for subsequent examination. The other viscera should also be carefully inspected. The thorax should be last examined; because this enables us the better to ascertain the descent of the diaphragm, and the arching of the chest, which takes place in asphyxia, than when we open the chest before the abdomen. The cartilages of the ribs should be divided as close as possible to the ends of the ribs, as thus a larger opening is made in the chest. The position and appearance of the lungs and heart should be noted, and their engorgement with blood, or the emptiness of the great vessels, ascertained. When it is necessary to examine the spinal canal, the body must be laid on a table with the face downwards: an incision is to be made

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along the whole spine, from the occiput to the sacrum, the integuments are to be separated on each side, so as to expose the posterior portion of the vertebræ, which may be divided near the transverse processes by a saw, the *rachitome*, or by cutting plyers. A triangular piece should also be sawed out of the occipital bone at the foramen magnum. This will expose the whole spinal canal.

Homicide may be accomplished by several modes that may sometimes be ascertained by examination of the body.

Death from Suffocation

Death by *Asphyxia* or suffocation may be produced by drowning, by hanging, by strangulation, and by mephitic air.

1. *Drowning* may produce the fatal effect in two different modes. In some the suddenness of the shock, or the surprise instantaneously arrests both the functions of circulation and of respiration; no struggle precedes death. This species of drowning has been justly compared to syncope; and hence has been by Desgranges termed *asphyxia syncopalis*. In others the circulation goes on for some time after the respiration has been interrupted; the animal struggles, makes vain efforts at inspiration, and portions of air are forced out of the lungs by a convulsive effort of the muscles of respiration. The circulation of unoxygenated blood through the brain seems to act as poison on that delicate organ; and the consequence is diminution of nervous energy over all the body, by which the play of the heart is enfeebled and the animal soon dies. In this case the brain is usually found congested with dark blood. This state has been aptly termed *aphyxia congestiva*. This difference in the phenomena may account for the great difference perceived in the bodies of drowned persons, and also for the difference in the chances of recovery after submersion. In the first species the pallor of the countenance is marked, and the features little altered. In the latter, the face will often appear swelled and livid, the tongue be protruded, the nose and air passages filled with frothy mucous, the brain and right side of the heart gorged with black blood. The body which has been sometime immersed is generally pale, the eyes are half open, and the pupils generally much dilated, the chest arched, and the diaphragm pushed down into the abdomen. These last signs are most conspicuous in those who have perished from *asphyxia congestiva*. When the person has retained his sensibility after falling into the water, the ends of the fingers are often found excoriated by his grasping at any object within his reach; and mud or gravel will often be found lodged below his nails. The blood in drowned persons generally remains fluid. These are the principal signs by which we can distinguish the extinction of life by drowning, from the cases in which the person has been thrown into the water after death. If we find in the stomach water containing any foreign bodies, such as fragments of straws or weeds, similar to those in the water in which the body was found, we may be sure that the person was living when immersed in the water: for no water will enter the stomach after death.

It may, however, be very difficult to distinguish a murder by drowning, from death by accidentally falling into water, or from a suicide. The most material circumstances will be, the marks of struggle near the spot where the body has been immersed, the obstacles in the way, the impressions of the feet of more than one person leading to the water. We must also pay attention to appearances of injuries on the body, which could not have occurred from simply falling into the water; such as marks of strangulation on the neck, or wounds inflicted by deadly instruments.

2. *Hanging* produces most of the internal appearances just described; such as turgescence of the vessels of the head, livor of the face, fluid black blood in the lungs and right side of the heart, protrusion of the tongue, and the nose loaded with mucus: but besides these, we usually find a mark round the neck; and when the person has undergone a public execution, especially when the *drop* is employed, there is often luxation of the neck, and fracture of the *processus dentatus*. Ecchymosis is generally found under the mark of the rope: sometimes this mark is not apparent until some hours after death, but dissection will shew the cellular tissue, beneath the rope, dry and compressed. The face is generally less distorted, the eyes less prominent, in those in whom luxation of the neck is produced by the drop, than when the struggle is more protracted. Recovery is hopeless in the first case, but has sometimes followed the asphyxia produced by mere strangulation, which seems to cause a stupor, that is, however, soon fatal, if the person be not soon relieved.

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In examining the body of a person found suspended by the neck, we must determine whether this be really the mode in which life was extinguished, or whether the body was suspended after death. The absence of the usual marks of hanging, the position of the rope-mark on the neck, the presence of other mortal injuries, the appearance of the rope are all important objects of consideration. These become of the utmost importance in the difficult cases, where there is a doubt whether the person was murdered or committed suicide. We must rely for a solution of the problem on the indications just noticed, and the previous history of the individual.

3. *Strangling* may be accomplished by drawing a rope tightly round the neck, or by forcibly compressing the anterior of the windpipe, after the manner of Burke and his imitators. In the first, the mark round the neck will generally be nearly circular and not inclined to the ear or occiput. In the latter, marks of fingers will often be perceived on the neck, or a circular depression will be found on the front of the windpipe, and sometimes some of its cartilaginous rings will be broken or displaced. The signs of suffocation will be equally present, as in hanging; but if the mark of the cord be on the *lower* part of the neck, it cannot be a case of death by hanging.

Suffocation has sometimes occured from bulky substances sticking in the gullet, and compressing the trachea. Assassination has also been effected on infants, or on feeble individuals, by covering up the mouth and nose. This last mode leaves no external marks of violence, and can scarcely be detected, except by the appearances of suffocation found after death.

4. *Mephitism*, or death from irrespirable gases, often happens accidentally, but is seldom the mode of assassination, except in cases of infanticide: and will be noticed under Toxicology.

In every case of suffocation our attempts at reanimation should be directed to renew respiration by inflation of the lungs, to restore the animal heat by exposure to warm pure air, and by assiduous frictions of the surface, to rouse by stimuli, and by brushing the soles of the feet and palms of the hands, to relieve cerebral congestion, when necessary, by moderate and cautious bleeding.

Death from Starvation.

VII. Death from Starvation. Cases may occur where it is important to distinguish this from other modes of the extinction of life. In such cases the cutaneous veins disappear, the skin has become harsh and has a shrivelled look; the fat has disappeared, and the soft parts are mostly wasted; the gums desert the teeth; the eyes are commonly more or less open and bloodshot; the tongue and fauces are dark and dry; the stomach shrunk, blackish and ulcerated on its internal surface; the intestines resemble a cord; the gall bladder is gorged with bile, which stains the intestines to a considerable extent; the heart is wasted, and the great vessels are almost empty; the body exhales a most offensive odour of putridity, even before life is extinct.

The period required to destroy life in inanition is very

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various, and appears to be shorter in the young and vigorous than in persons of middle life, in men than in women. In some comatose diseases, and in persons reduced by previous illness, the life under inanition has occasionally been greatly protracted; and when there has been stupor with occasional intermissions, an astonishingly small quantity of liquid aliment has prolonged life for many weeks, months, or even years. Some of the published cases of *fasting* are apocryphal; but in others where the quantity of nutriment has been extremely small, the individuals may be considered as in the state of hybernating animals, where the diminished nervous energy renders the waste of the system exceedingly slow. Those who are deprived also of drink perish soonest of inanition; and those who are confined in dry warm air, than those exposed to a moist, cool atmosphere.

Death from extremes of Temperature.

VIII. Death from Extremes of Temperature.

1. *From extremes of cold.* After the sensation of tingling in the fingers and toes, exposure to extreme cold is soon followed by languor, loss of sensation, and irresistible propensity to sleep, which is so oppressive, that even the known fatality of the indulgence while exposed to the cold is insufficient to prevent the sufferer to seek repose. Cold does not seem to produce a painful death. In arctic regions the best preservatives against extreme cold are, woollen garments next the skin, with furs and dressed leather over them, a free use of warm diluents, and avoiding wine and spirits.

2. *From a much increased temperature*, the fatal effects may be *scalding* or *burning*, according to the medium applied. This mode of extinction of life leaves very obvious traces on the body. Sometimes fire has been applied to the body after death, to conceal a murder. This fact suggests the propriety of the medical man examining a scorched body minutely, lest there be wounds on its surface, inflicted during life. If the person has lived sometime after the scorching, in general there will be found a ring of inflammation surrounding the eschars: but this only takes place when the burning has not been so severe as to sink the powers of life beyond the capability of reaction.

An increased temperature may be insufficient to vesicate or destroy the skin, yet may prove fatal; as is well known in what is termed a *coup de soleil.* This is a species of apoplexy, chiefly induced by the direct influence of the sun on the head, and appears to be similar to the effect of the *Khamsin* or *Simoon* of the desert.

3. *Death from lightning* is not wholly to be attributed to the high temperature, but partly to the impulse or shock instantly affecting the brain, and paralyzing the heart: yet as the marks of singeing are often observed on the bodies of those killed by lightning, it may be here considered. The skin is sometimes discoloured in stripes or oblong patches; at other times the surface has no mark of injury, but the viscera have been observed more or less affected, and occasionally there is a small perforation on the skin. The blood is described in every case as remaining fluid, and the corpse runs rapidly to putrefaction.

Wounds.

IX. Wounds. The examination of wounds, whether fatal or not, often becomes an important branch of legal medicine. Wounds are usually divided into contusions, lacerations, incisions, stabs, gunshot and poisoned wounds. Each kind requires to be minutely examined, and described, as they are in approved works on surgery. The degree of danger from each should be familiar to the jurist; and he should recollect that there is scarcely any wound which may not become *incidentally* fatal from improper treatment, or peculiarities in constitution. Punctured wounds or stabs require minute attention; for there have been instances in which death has been produced by an instrument not thicker than a pin, thrust into the brain, the spinal marrow, or the heart.

Poisoned wounds belong to Toxicology.

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Wounds are more or less dangerous according to their locality.

1. *Wounds of the head* are always dangerous, especially if the blow has been considerable. The person so wounded may die without separation of the integuments or fracture of the bone; as happens in what is termed *concussion* of the brain. Contusions which do not divide the skin may fracture the skull; or the inner table of the skull may be fractured without the outer being broken or depressed. Even wounds of the integuments may prove fatal, from inflammation extending inwards to the brain. Punctured wounds of the head are more dangerous than cuts, as more likely to excite fatal inflammation. When the brain or its meninges are injured, all such wounds are generally fatal.

Wounds of the face or organs of sense are often dangerous, and always disfiguring. Malicious disfiguring of the face was made a capital felony in the reign of Charles II., by the *Coventry act;* but the monstrous anomaly pointed out by Filangieri, that disfiguring *with the intent to disfigure* was punished with death, while *the intent to murder* was not capital, no longer disgraces our statute book. Wounds of any of the organs of sense are generally dangerous, and always produce serious inconvenience.

2. *Wounds of the neck* are always very serious wherever more than the integument is divided. The danger of opening large blood-vessels, or injuring important nerves, is imminent: even the division of a considerable vein in the neck has proved immediately fatal, from the entrance of air into the vessel, and its speedy conveyance to the heart. A blow on the side of the neck has instantly proved fatal, either from the blood being forced back into the brain, or from injury to the superior parts of the par vagum, the great sympathetic, or the other cervical nerves. Dislocations and fractures of the bones of the neck prove instantly fatal.

3. *Wounds of the Chest* are always serious, when the cavity is penetrated, though persons have recovered from wounds of the lungs, and have even survived for some time considerable wounds of the heart. This last is an important fact; because we are not always to consider the spot where the body of a person killed by a wound of the heart, and apparently remaining where he fell, is found, as that in which the death-wound was inflicted. Instances have occurred of persons surviving severe wounds of the heart for several days. Fractured ribs are never without danger; and the same may be said of severe contusions of the chest, from the chance of inflammation extending inwards. Wounds penetrating both sides of the chest are generally considered as fatal, though animals have recovered after having both sides of the thorax penetrated, and the wounds kept open for some minutes.

4. *Wounds of the Abdomen*, when they do not completely penetrate, may be considered as simple wounds, unless when inflicted with great force, so as to bruise the contents of the cavity; in that case, they may produce death without breach of surface, as sometimes happens from blows or kicks on the belly. Wounds injuring the general peritonæum, or that duplicature of it investing the stomach and intestines, are highly perilous, from the risk of severe inflammation. Wounds of the stomach or intestines, or of the gall bladder, generally prove mortal, from the effusion of their contents into the general cavity producing fatal inflammation. Wounds of the liver, spleen, or kidneys, are generally soon mortal, from the great vascularity of those organs.

5. *Wounds of the Extremities*, when fatal, may generally be considered so from excessive hæmorrhage, from the consequences of inflammation and gangrene, or from the shock to the system, when large portions of the limb are forcibly removed, as in accidents from machinery, and in wounds from fire-arms.

Forensic Medicine. Toxicology

X.—Toxicology.—This most important branch of legal medicine has been more thoroughly investigated than any other part of Medical Jurisprudence. A poison may be defined *a substance capable of impairing or extinguishing the vital functions, in a great majority of cases.* This limitation is necessary, because some of the most deadly substances, in small doses, may be taken not only with impunity, but with salutary effects; and habit renders doses of them innocuous, which would destroy an individual unaccustomed to their use. Some poisons act directly on the organs to which they are applied; others appear to act by their influence on the nervous system. Some appear to act merely as irritants or escharotics; others by directly impairing vital functions; and some have a twofold action. The manner in which poisons affect the system appears to be either through their direct influence on the extremities of the nerves to which they are applied, or by absorption, and consequently by the circulating fluids. The rapidity with which some poisons, as hydrocyanic acid, act, favours the opinion that their influence is instantaneously conveyed to the vital organs by nervous communication. The detection of poisons, in some instances, in the blood, or in the exhalations or secretions, favours the opinion of the circulation being one channel by which they are carried to the system; a fact which is further confirmed, by the effect of ligature, or of division of vessels, in preventing the constitutional affection of the poison on the system. Some poisons exert their deleterious influence on one organ, or set of organs; others generally affect the system. Poisons, classed according to their effects, may be divided into *irritants*, *narcotics*, *narcotico-acrids*, and *septics*. Their action is modified by the tissue to which they are applied, the constitution of the individual, the quantity of the poison, and its mechanical state.

The mode of treatment of poisoned persons depends on the nature of the poison. The first indication is undoubtedly to evacuate the poison as speedily as possible, by the stomach-pump or by emetics; the second, to administer antidotes, if any such be known for the particular poison; the third, to shield the stomach and *primæ viæ* against the acrimony of the substance; and, lastly, to obviate any violent or untoward symptoms they may produce, by all the resources of our art.

The evidence of poisoning may be presumptive, or positive, physical, or moral. The physical proofs are derived from the symptoms, from experiments on the lower animals, and from a chemical investigation of the *ingesta* or *egesta*. The symptoms, however, only supply us with probable evidence; but the most important inferences they afford are deduced from the simultaneous occurrence of similar symptoms, in more than one individual previously in good health, soon after a meal on the same articles of diet. Experiments on the lower animals with the remains of the ingesta, or portions of egesta, are not much to be relied on, as all animals are not equally susceptible of the same poisons; and what is deleterious to one is innocuous to another. Some poisons, however, such as arsenic and corrosive sublimate, are equally poisonous to all. Such experiments we consider as scarcely justifiable, except in the cases of some vegetable poisons, which cannot otherwise be readily detected. The evidence from chemical analysis of the stomach, of the ingesta or of the egesta, is the most unexceptionable. The refinements of modern chemistry have enabled us to detect surprisingly minute quantities of inorganic poisons, and even of some vegetable poisons. In such investigations, the contents of the stomach, or egesta, should be put into clean vessels; if too thick, diluted with distilled water, boiled, and when cold, filtered through muslin, and then through paper. If the filtered liquor contain much animal matter, this must be separated, as it obscures the various tests to be applied. This in general is best done by acidulating the liquor with vinegar, by again boiling and filtering. Sometimes it requires to be further clarified, by the addition of animal charcoal, or of nitrate of silver, which separate all the animal or vegetable matter. To portions of the clear and colourless liquid thus obtained various tests are applied, the effects of which will decide the nature of the poison. Sometimes the whole poison may have been so evacuated by vomiting, or taken up by absorption, that not a trace remains in the contents of the stomach. In this case we can occasionally detect it, by cutting the stomach into pieces, boiling them in distilled water, purifying the liquid by some of the processes already described, and then applying the tests. Narcotic poisons are easiest detected by their smell; sometimes we can climinate one or more of their peculiar ingredients by chemical means, but frequently we have no better means of detecting them than by the symptoms they produce, and the moral evidence of the case, or the morbid appearances on the body after death.

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We are not to regard the livid appearance of the body as evidence of poisoning; it is not always present in cases of poisoning, and may arise from other causes. The rapid putrefaction of the body is as fallacious an indication. The very reverse is sometimes the fact. The classes of irritant and narcotico-acrid poisons are usually indicated by inflammatory appearances in the primæ viæ, but these are not invariably present; and cases often occur of which the moral evidence may be strong, yet the direct evidence may amount to no more than a probability.

The moral evidence of poisoning may sometimes be best collected by the medical attendant. He may be the only witness to the conduct of the accused; he may have observed him suspiciously active in removing every trace of the potion administered, or of the egesta in which a poison might be detected; he may have observed the guilty confusion of the suspected person, or heard his attempts to explain a fatal mistake, if the administration has been traced to him; or the physician may have been the chief depositary of the dying declaration of the sufferer. All these things it is his duty to note down, and to transmit to the proper authorities.

Poisons are derived from the inorganic or organic kingdoms of nature. The first class may be metallic, earthy, alkaline, and simple chemical substances, and gaseous bodies: the second vegetable and animal poisons.

Metallic Poisons.

1.—Metallic Poisons.—Of these arsenic, quicksilver, copper, lead, antimony, zinc, tin, bismuth, chrome, silver, gold, are the most important.

1. *Arsenic* is poisonous in all its combinations. Its most usual preparations given as poisons are, the blackish oxide or fly powder, the white oxide or arsenious acid, the sulphurets, and the combination of arsenious and arsenic acids with alkalis. All are very deadly, even in small doses, whether swallowed, introduced into the anus or the vagina, applied to the abraded surface, or even when extensively applied to the whole skin. The symptoms commence usually within an hour after the administration; and are, nausea, vomiting, great heat and pain in the stomach, purging, intense thirst, severe spasms in the limbs and body, prostration of strength, pallor of the face, a feeble pulse; sometimes convulsions precede death. In a few cases the symptoms of an irritant poison are wanting, and the arsenic appears to be fatal by immediately inducing paralysis of the heart.

The fauces, gullet, and stomach are often found marked by inflamed patches of a deep vinaceous colour, produced by blood effused under the villous coat of the stomach. Sometimes the villous coat appears corroded or thickened, but the stomach is seldom perforated. When the villous coat has suffered erosion, the poison has generally been given in the solid form, and grains of it may often be picked

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off the surface of the stomach for analysis. The inflammation seldom reaches to the jejunum; but, though the greatest portion of the small intestines and the colon escape, marks of irritation are often observed about the rectum, especially if the purging has been violent. Various antidotes have been proposed, such as charcoal and magnesia; but the only substance that seems to deserve any reputation is the recently prepared *hydrated peroxide of iron*, promptly administered in large doses.

The means of detection, when the arsenic is solid, are easy. Introducing it, with charcoal powder if it be white arsenic, or with black flux if it be orpiment, into a small tube, and applying gradually the heat of a spirit lamp, will afford a blackish, shining, metallic crust, the interior of which is crystalline. A portion of this, exposed to heat, exhales as a white smoke, and gives out an alliaceous odour. Another portion, slowly heated in a tube open at both ends, is converted into minute tetrahedral crystals. When it exists in solution in the contents of the stomach, we have to clarify the liquid, by the means already mentioned, and to apply tests; of which the most approved is a stream of sulphuretted hydrogen, which throws down a lively yellow precipitate; the ammoniaco-nitrate of silver, which gives a yellow precipitate, that soon fades to a brown; ammoniaco-sulphate of copper, which gives a green precipitate. Either of these precipitates heated with black or soda flux, in a glass tube, will afford the crust already described. These indications leave no doubt of the presence of arsenic; and from the $\frac{1}{200}$ or $\frac{1}{300}$ of a grain may be converted into a sensible metallic crust. Arsenic seems to have a tendency to preserve from putrefaction the stomachs of persons poisoned by it; and it has been detected in bodies that have been from four months to two years buried.

2. *Mercury or Quicksilver.*—This metal in its pure state has been supposed innocent; but when in the state of vapour it is well known to be speedily deleterious, and to produce all the symptoms of mercurial poison. The most usual mercurial poisons are corrosive sublimate, or bichloride of mercury, its oxides, and sub-salts. The long-continued use of calomel is capable also of acting as a poison; but almost the only mercurial poison criminally administered is corrosive sublimate, though, from its detestable taste, it cannot be given by the mouth as a secret poison.

The usual indications are a styptic taste, then burning of the throat, violent vomiting, great distress in the stomach and bowels, violent cholic and severe purging, blood mingled with the matter brought up by vomiting, or ejected by stool. The symptoms often simulate dysentery: the face at first is often flushed, the eyes sparkling; soon the powers of life sink, the voice is lost, cold clammy sweats bedew the surface, perception of external objects is lost, and convulsions close the scene. When the substance is given in small doses, or if the mercurial be a milder preparation, after dysenteric symptoms ptyalism supervenes; the person may sink from the violence of that affection, the fauces may become ulcerated, and gangrene may ensue. If ptyalism follow the administration of a single large dose of mercurial, it is always to be regarded as a formidable symptom. When the person survives, he may suffer from mercurial palsy.

The effects of mercurial poisons are indicated after death by the following appearances. The fauces are generally more affected than from arsenic, and the inflammatory appearances are more diffused over the alimentary canal. Destruction of the coats of the stomach are often observed, either the consequence of the escharotic power of corrosive sublimate, or of ulceration. Peritonæal inflammation is not uncommon; and irritation of the urinary organs, perceived during life, is marked by inflammatory indications found after death.

We possess in whites of eggs, milk, and gluten of wheat, very effectual antidotes for the poison of corrosive sublimate, provided they be given soon after the poison. The first is the most powerful. The secondary symptoms must be met by antiphlogistic remedies and venesection.

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Mercurial poisons are easily detected when we obtain them in substance, but not so readily when mingled with the contents of the stomach. Corrosive sublimate is readily decomposed by several animal substances, and therefore we are not likely to detect it unchanged in the contents of the stomach. It is there usually converted into calomel, either in whole or in part. When held in solution, it is easily detected by Sylvester's method, *i.e.* by dropping a little of the suspected liquid, slightly acidulated, on a gold plate, or a gilt card, and touching the gold surface, through the liquid, with a piece of zinc or iron wire. Professor Traill employs a similar method to separate the whole mercury from its solution. He wraps a gold leaf round a slip of zinc, and immerses it in the suspected liquor, slightly acidulated—the mercury is precipitated; and scraping off the gold and the tarnished surface of the zinc, he introduces them into a small tube, and the heat of a spirit lamp is sufficient to produce a ring of brilliant metallic globules. He has employed a similar method to separate arsenic from its solutions.

In all probability the mercurial will not be found in the stomach in a soluble state. In this case we have to form the contents of the stomach into a pulp, and to pass a stream of chlorine through the mass, when the mercurial present will be converted into bichloride, which may be separated by filtration; drive off the excess of chlorine by boiling the liquid, and then either precipitate the mercury, by introducing into the liquid a cylinder of pure tin, according to Devergie's method, or by Traill's combination of zinc and gold leaf. The tarnished surface of the metals in either case is to be scraped, and the powder so obtained introduced into the tube and heated, as already described.

When we have much corrosive sublimate to operate on, we may try it by lime water, which throws it down of a deep yellow; by alkalis, which form with it an orange precipitate; by protomuriate of tin, which gives a slate-grey powder; and by hydriodate of potassa, which forms a splendid scarlet precipitate.

3. *Copper.*—The poisonous effects of the salts of copper have long been known; but though little likely to be used as secret poisons, they sometimes produce death from being accidentally mingled with food, as in the use of culinary utensils of copper. The symptoms are those of other irritant poisons, to which is added spasmodic rigidity of the limbs, in some cases amounting almost to tetanus. Salts of copper may produce salivation, and also jaundice. The morbid appearances are not very characteristic.

Albumen of eggs appears an antidote of some power against the salts of copper, and therefore, after evacuating the stomach, the whites of raw eggs should be administered. Inflammation should be obviated by antiphlogistic means.

The poison of copper may be sought for by boiling the contents of the stomach with acetic acid; this will dissolve every preparation of copper, and enable us to separate them from animal and vegetable matter by the filter. We may, if necessary, concentrate the solution by evaporation; and if the addition of ammonia give the solution a blue colour, we may be satisfied that it contains copper. A stream of sulphuretted hydrogen throws down a brown precipitate from the solution of copper; and if the quantity of copper be considerable, a piece of bright polished iron will become coated with a film of copper.

4. *Lead.*—The poison of lead is of considerable consequence, although never used as a secret instrument of revenge. Its oxides and salts all appear to be deleterious, but those from which accidents have most commonly happened are litharge, white lead, and sugar of lead. These

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often find their way into the stomach, from little-suspected sources, and produce a species of poisoning with very peculiar symptoms. Leaden pipes and cisterns are acted on by water, especially by soft rain-water, and the carbonate of lead thus formed being soluble in an excess of carbonic acid, is liable to enter the human system with the food. Acescent articles of diet act on leaden vessels, and, when aided by heat, on the plumbiferous glazes of our earthenware. These are the most general sources of this poison; but persons engaged in works where white lead is largely used, smelters of lead ores, painters, and potters, are liable to the same deleterious influence. The symptoms produced are obstinate constipation, severe tormina, with the symptoms commonly known by the name of *painter's colic, colic of Poitou*, and of *Devonshire*. After these have subsisted for some time, the person begins to have paralysis of the limbs, first of one or both arms; in general the extensor muscles suffer before the flexors, and the palsy may then become general in that limb, or extend to other parts. The preparations of lead, when given in large doses, appear to act as irritant poisons.

Orfila found that animals poisoned by sugar of lead had a preternatural whiteness of the villous coat of the stomach, if they perished speedily; but, if their death were protracted, the inner coat of the stomach was reddened. The stomach has often been found corrugated after death.

Frequent ablution of the surface is the best prophylactic for those much exposed to the powder of the preparations of lead; and when lead has been introduced into the system with the food, the best means of obviating the return of the evil is by rigidly excluding lead from all culinary and economic purposes. Hard water is less liable to act on lead than soft water, and hence the impropriety of lead cisterns for rain water. Mercury seems to have a beneficial effect in lead colic, especially when conjoined with opium.

Lead is easily detected. To whatever articles it is suspected to enter add vinegar, and boil; filter the solution and all the lead will be in the clear liquor. If in large quantity, it may be detected by the sweetish astringent taste of the liquid; part of which may be tried by the addition of a solution of sulphuretted hydrogen, or of hydrosulphuret of ammonia, which instantly darkens the most dilute solution of lead; another portion may be tried by bichromate of potassa, which throws down solutions of lead of a brilliant yellow; a similar colour is formed with them and hydriodate of potassa.

5. *Antimony* is rarely a poison; because its most active and best known preparations are violently emetic, and thus counteract its effects. Emetic tartar, when given to the lower animals, if vomiting be prevented by tying the gullet, causes inflammation of the lungs and stomach; and this would probably be its effects on man. The lungs appeared a mixture of orange-red, and violet-blue, and they were gorged with blood, which prevented the usual crepitus. It was also fatal when applied to a wound. The stomach was violet coloured, thickened, and covered with tough mucus, the intestines empty, in a man killed by emetic tartar.

The best antidote for this poison is decoction of peruvian bark, especially of *cinchona cordifolia*.

The detection is not difficult: sulphuretted hydrogen throws down a rich orange-red precipitate. When the antimony is mixed with animal and vegetable matter, add first a little muriatic acid to precipitate the contaminating substances, and then tartaric acid to dissolve any antimonial present. This will afford by filtration a clear liquid for the application of the tests. The sulphuret is best reduced by Dr. Turner's process; *i. e.* passing a stream of hydrogen over it when heated to redness in a tube.

6. *The other metals*, though affording some poisonous salts, scarcely require notice in this place. *Zinc* in solution may be detected by a stream of sulphureted hydrogen affording a whitish precipitate. *The muriate of tin* affords one of a rich purple, the powder of Cassius, with deuto-muriate of gold; and when strong, coagulates milk completely. *Sub-nitrate of bismuth* may be detected by calcining in a moderate heat the contents of the stomach, and adding diluted nitric acid to form a solution, from which water throws down a white precipitate. The soluble *salts of silver* are thrown down by alkaline and earthy muriates; and the precipitate is easily fusible into *horn-silver*. A plate of copper becomes silvered by immersion in the solution of silver. *Gold* may be detected by solution in nitro-muriatic acid; which solution affords the purple powder of Cassius with muriate of tin; and the neutral solutions of gold instantly gild silver or copper immersed in them.

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II. Earthy and Alkaline Poisons.

Earthy and Alkaline Poisons.

1. *Baryta.*—Both the carbonate and pure baryta are very poisonous, as are the soluble salts of this earth. The symptoms are those of irritant poisons: the senses then become blunted, the respiration feeble, and convulsions close the scene. The stomach is found inflamed, and the brain shews congestive apoplexy. The antidotes are any of the alkaline sulphates, which instantly form with all the poisonous salts of baryta, insoluble, inert compounds. Sulphuric acid, or sulphates, are also the tests of this earth: but it might be confounded with strontia, the salts of which do not seem poisonous, except in as far as they are acrid. The best distinction is obtained by procuring a muriate of the suspected salt, and dissolving it in alcohol. The muriate of baryta imparts a yellow colour to the flame of spirit; the muriate of strontia, a fine red.

2. *Lime* is only poisonous as an acrid. The antidotes for it are phosphates of soda or potassa, and water impregnated with carbonic acid. The detection of the salts of lime is easy. Its properties when pure are alkaline: it forms with sulphuric acid a substance of little solubility; but phosphoric and oxalic acids precipitate it from all its soluble combinations.

3. *Potassa* and *Soda.*—The pure alkalis and their carbonates are poisonous. Several fatal accidents have happened from them. They act as strong irritant poisons, producing intense heat and pain in the abdomen, then cold sweats, tremors, and convulsive twitchings in the limbs, the stools are tinged with blood, and membranous flakes are mixed with the egesta. When the person lives some time, general peritoneal inflammation is observed after death. Nitrate, and chlorate of potassa are irritant poisons in large doses, producing dangerous inflammation of the stomach and bowels.

The best remedies are large quantities of mild oil. The tests of the alkalis are obtained from their combinations with different acids, and the manner in which they colour the flame of the blowpipe. When nitrate or chlorate of potassa can be had in the solid form, the first may be known by its ready deflagration with charcoal in a crucible; the second by putting a drop of sulphuric acid on a mixture of the salt with sugar, which it instantly ignites.

4. *Ammonia and its salts.* They all act rapidly as irritant poisons, and have besides a violent effect on the nervous system, especially on the nerves of the spinal cord. This last effect is principally produced by pure ammonia and its carbonate. Convulsions are caused by the too long continued inhalation of the vapour of ammonia, which has several times proved fatal to man, terminating in severe bronchitis. For this species of poisoning, muriatic acid vapour is the best remedy. On the reception of carbonate of ammonia in the stomach, we should administer diluted vinegar instantly.

We detect the presence of ammonial vapour by the smell, and by a rod dipt in muriatic acid, which gives rise to white fumes of muriate of ammonia.

5. *Alkaline sulphurets* are all poisonous, chiefly from the

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readiness with which they give out a large quantity of sulphuretted hydrogen gas, which is poisonous when inhaled, and when injected in quantity into the alimentary canal. The villous coat of the stomach, in cases of poisoning by alkaline sulphurets, resembles in colour the skin of a toad, and the muscular coat is congested with blood. The alkaline sulphurets act as narcotico-acrid poisons. Their presence is ascertained by a weak acid, and exposing a piece of paper dipt in sugar of lead to the fumes.

Acid Poisons.

III. Acid Poisons. The three mineral acids are only poisonous from their corrosive qualities, destroying rapidly the tissues to which they are applied.

1. *Sulphuric acid*, when strong, decomposes and blackens animal matter by evolving their carbon. It disorganises the fauces, gullet, and stomach; when not speedily fatal it lays the foundation of stricture of the gullet, and the patient is long harassed by dysuria and constipation. It is a capital felony to throw acid maliciously in the face.

2. *Nitric acid* destroys the animal tissues, and gives them a yellow hue, especially in the fauces, and when applied to the skin.

3. *Muriatic acid* destroys the tissues also, but renders the fauces usually whitish, as if the surface were of ivory. The symptoms produced by the three acids are similar, and the best remedies are the same for all, viz.—the copious use of mixtures of chalk or magnesia with milk.

The three acids destroy the clothes, corroding them when strong, and when diluted, staining them of a reddish brown. This circumstance becomes of importance in cases of maliciously throwing acid on any person, when no part of the acid liquid has been preserved. The stained portions of clothes, soaked in distilled water, will give out the acid; if sulphuric acid be present, it is best detected by nitrate of baryta, which gives a white precipitate, insoluble in pure nitric acid. Muriatic acid is detected by the addition of nitrate of silver, which throws down insoluble muriate of silver. Nitric acid is best recognised by its effect in destroying the colour of sulphate of indigo, when heated with it in a tube.

4. *Oxalic acid* is a most deadly poison. It differs from other acids derived from the vegetable kingdom in not containing hydrogen; being like the mineral acids, a binary compound. Its taste is so intensely sour that it cannot be employed as a secret poison; but it has been swallowed by mistake for sulphate of magnesia, so as to prove fatal. Its alkaline salts are almost equally poisonous, especially the binoxalate of potassa, or salt of *sorrel*, and they are speedily fatal when applied to wounds. Oxalic acid renders the tongue red and inflamed, and it corrodes the stomach; burning pain in the primæ viæ speedily come on, cold clammy sweats, a faint and fluttering pulse succeed, and palsy of the heart soon appears; proving that this substance is not only an acrid but a true narcotic. Unfortunately its effects are so violent and sudden that there can little be done by art to save the patient. Instant evacuation of the stomach, and the exhibition of chalk mixtures are the best means to be employed. Even when the person survives the immediate effects, he often dies of the inflammation or the corrosion of the alimentary canal.

The best mode of detecting oxalic acid is to precipitate portions of it by solutions of lime and magnesia. The precipitate by the first is not decomposable by any acid: sulphate of copper gives a precipitate with oxalic acid, insoluble in a little muriatic acid; and the precipitate with nitrate of silver, when dried, deflagrates with a gentle heat.

Simple Substances with Poisonous Qualities.

IV.—Simple Substances with Poisonous Qualities.

1. *Phosphorus*, even in very small quantities, is poisonous: two grains have proved fatal to a man. In that case there were sugillations on the belly and thighs, the scrotum was bluish and phosphorescent, the chest contained much fluid, dark blood, and the muscular coat of the stomach appeared inflamed, with dark spots about the cardiac and pyloric orifices. Evacuation of the stomach, and the administration of mucilaginous, but not oleaginous substances, are all the means we should employ to give relief in such cases. When the patient lives for some time, it will be difficult to detect the poison, unless the morbid appearances above noted may be considered as characteristic. Solid phosphorus is easily detected, by its inflammability.

2. *Iodine*, and *Hydriodate of Potassa*, are active substances, which, if given in excess, are apt to produce irritation of the system: vomiting, excessive languor, a feeble pulse, pains in the stomach, and cramps in the limbs; bilious vomiting and purging have followed large doses of iodine. It stimulates the liver, causes absorption of indolent glandular tumours; and, it is said, that its long-continued use has caused the disappearance of the testes and mammæ.

In dogs poisoned by it, the stomach was found inflamed, with numerous ulcerated points on its villous coat. No antidote is known. Its detection is easy. Boiled solutions of starch are delicate tests of the presence of iodine, or of hydriodic acid, by the intense blue colour produced. If hydriodate of potassa be present, the colour is evolved, on adding to the starch a drop or two of sulphuric acid.

3. *Bromine* is more poisonous than the last substance, but it is so rare a substance, that it is unnecessary to describe its effects or mode of detection.

Gaseous Poisons.

V.—Gaseous Poisons.—Of these some are fatal from the irritation they produce, A; others are narcotic, B.

A.

1. *Chlorine*.—This gas destroys life, if incautiously inhaled, by the irritation it produces. It causes violent constriction of the epiglottis, and severe pain in the chest, even when diluted. It disinfects air contaminated by animal emanations. Its solution in water kills dogs; and when injected into a vein, it speedily destroys life. It is most certainly detected by its smell.

2. *Hydrochloric gas*, or *muriatic acid gas*, is still more irritating and destructive. It is largely emitted in the manufacture of soda from salt, and is then most hostile to vegetation; $\frac{1}{3000}$ of it contaminating the atmosphere, so as to destroy plants.

3. *Sulphurous acid gas* is also most suffocating; is, even when much diluted, very destructive to vegetation; and has, as emanating from burning sulphur, sometimes been employed to commit infanticide. It renders the lungs very livid.

4. *Nitric oxide, and nitrous acid vapour*, are poisonous irritant gases, that cannot be respired, unless largely diluted. The attempt to respire the former nearly proved fatal to Davy. The fumes of the latter have accidentally proved fatal to individuals, producing burning sensations in the throat and chest, an expectoration of yellowish matter, and alvine dejections of a bright yellow colour. Before death the body becomes livid, the breathing laborious. Vapour of ammonia cautiously inhaled may relieve from the effects of this gas, of hydrochloric, and of sulphurous acid gases: but we have no means of detecting any of these poisonous gases, in the small quantity they ever can exist in the human chest, except by the sense of smell.

5. *Ammonia* is not only irritating when received into the lungs, but is, as we have already said, narcotico-acrid.

B.

6. *Nitrous Oxide*, the exhilarating gas of Davy, is narcotic, yet can scarcely be considered as poisonous, since it may be inhaled several times a-day without injury; but it seems to have a tendency to cause cerebral congestion

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7. *Sulphuretted Hydrogen* is one of the most poisonous of gases, destroying life when injected into the intestines, or into the cellular tissue, when received into the lungs, or even when extensively applied to the surface of the body. It is largely given out in the corruption of some kinds of animal matter. Many serious accidents from this gas have happened in clearing out the Parisian *fosses d'aisance*. The symptoms are instantaneous asphyxia, with discharges of bloody froth from the mouth, and convulsive movements of the limbs; motion and sensibility soon cease, the lips become livid, the eyes close, and lose their lustre, the surface becomes cold, the action of the heart is tumultuous, then feeble, and before death complete tetanus often comes on. Even when the gas does not kill, it produces severe tormina, nausea, and drowsiness. The body of one killed by it quickly becomes putrid; the skin is livid, and soon meteorized; the brain tender, and of a greenish hue. The proper treatment of persons suffering from this gas is to carry them into pure air, to dash cold water and vinegar over the body, to rub the surface diligently with warm flannels, but to admit air freely to the surface, while the palms and soles are to be strongly brushed. Lavements of cold water and vinegar should be first used, and then lavements containing common salt; when the heart beats violently blood should be abstracted.

This gas is well known by its smell resembling that of rotten eggs. Solutions of sugar of lead are very delicate tests of its presence in minute quantity.

8. *Carburetted Hydrogen*, of various qualities, is given out by stagnant waters. It is one of the results of combustion, and is abundantly produced in coal mines, where it is the formidable *fire damp*. When the atmosphere is much contaminated with it, it oppresses the breathing, and produces headache and giddiness. When mixed in the proportion of about $\frac{1}{12}$, with the atmosphere of mines, it will explode on the approach of a flame; yet in such an atmosphere persons will continue to work for some time with impunity; but even if there be no risk of explosion, the narcotic effects of the gas begin to be perceived on those long exposed to it.

9. *Carbonic Oxide*, mixed with other gases, is given out by burning fuel, especially if moist, and burning slowly. It scarcely becomes an object to the toxicologist in its pure state. It is inflammable, rather lighter than atmospheric air, and has a disagreeable smell. It may be respired when diluted; but produces temporary intoxication, and when injected into the veins gives the blood a brown colour.

10. *Carbonic Acid.*—This gas is well known to be heavier than atmospheric air, to be totally irrespirable when pure, and to be speedily fatal to animals plunged in it. It is always present in the air in minute quantity; but is largely given out by the burning of all sorts of fuel, is produced in every species of fermentation, is formed in the respiration of all animals, and, under certain circumstances, it is given out by plants, particularly in the dark. From these sources, the air, in confined situations, may become impregnated with it, in a proportion inconsistent with the safety of man. Numerous instances of its fatal effects have been observed in the neighbourhood of large fires, in breweries, in crowded apartments; and in rooms where many plants are growing, it is unhealthy to sleep. When a confined atmosphere is much mixed with it, uneasy respiration is speedily felt, and the person may escape the danger by seeking the open air; but at other times drowsiness or stupor comes on, before any warning is given, and the individual loses the power of attempting his escape. When the gas is undiluted, it is almost immediately fatal to animals immersed in it; and even if the animal be made to respire pure air, while the whole body, except the head, is immersed in carbonic acid, life will be extinguished. After death from this gas, the features remain placid, the eyes open and brilliant, the body long retains its heat and flexibility. When the person has not been exposed long enough to extinguish life, the breathing may be stertorous and oppressive, the face flushed, the pulse feeble, the eyes prominent and wildly rolling about, the tongue swollen, and the saliva flowing out of the mouth. Forensic Medicine. Toxicology

The proper treatment consists in removing the patient into the open air, or into a well-ventilated room; the surface should be sprinkled with vinegar and water, and every few minutes rubbed dry with hot towels. If the valve bellows be at hand, the foul air should be first drawn from the lungs, and its place immediately supplied by fresh air, thrown in by the same machine. This alternation may be two or three times repeated, and then we should imitate natural respiration as much as possible, throwing in air by the bellows, and aiding the expulsion of the air by gentle pressure on the chest. Brushing the soles of the feet and palms of the hands with stiff brushes, stimulating the nose by a feather, or by ammonia, are useful auxiliaries. When animation is restored, it is time enough to put the patient to bed.

VI.—Vegetable Poisons.—These include most of the narcotic and narcotico-acrid poisons of Orfila. Narcotism begins with a sense of fulness in the head, then succeed a sort of intoxication, dizziness, headache, loss of voluntary motion, almost amounting to paralysis, sometimes convulsions, and finally, stupor and coma. These symptoms may not all be present; for each poison has its peculiar modification of the general symptoms. The *post mortem* examinations of those who perish by narcotic poisons do not generally throw much light on their mode of destroying life; and there are some diseases that bear considerable resemblance to narcotism. Thus, *Apoplexy* chiefly differs in there having usually been some warning before the fatal attack, and in coming on during a meal. Narcotism is generally perceived from half an hour to one hour, or more, after taking the poison. Narcotism is more gradual than apoplexy, and at first the person may be roused from his stupor. Apoplectics generally survive for a day, or often much longer. *Epilepsy* may generally be distinguished by the history of the case, by the abruptness of the attack, by the person being instantly rendered insensible, and by its rarely proving fatal on the first attack. One species of fatal *syncope* is more difficult to be distinguished from narcotism; and if it has not been witnessed, we do not know how it can be recognised after death. Vegetable Poisons.

1. *Opium.*—The deadly effects of this substance have been long known; and it was supposed to be a proximate vegetable principle, simple in its nature, and peculiar in its effects. Modern chemistry has shewn that opium, like many other active vegetable substances, owes its qualities to an *alkaloid*, which may be separated, by chemical processes, from many other ingredients. The first of these alkaloids was detected in opium about 1812; and the care with which this important drug has been since examined, has shewn it to be an exceedingly compound substance, consisting of not less than of thirteen, or perhaps of fourteen different vegetable principles, of which six are crystallizable. Of these, in a toxicological point of view, the most important are *Morphia* and *Meconic acid*. These two ingredients appear to exist in combination in opium; and when magnesia is added to a watery solution of opium, an insoluble meconate of magnesia is formed, from which the morphia, sparingly soluble in water, is taken up by alcohol; or, if we add muriate of lime to the liquid, instead of magnesia, we obtain meconate of lime, as an insoluble precipitate, and a soluble muriate of morphia; which last, when purified by several nice chemical manipulations, is obtained in minute, white, silky crystals. This is the valuable part

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of opium to the medical practitioner, as it is powerfully hypnotic, and is less liable to cause headache, nausea, and itching of the skin, than crude opium.

When either this substance or opium are administered in an over-dose, the symptoms are drowsiness and insensibility, but this state is often preceded by a slight excitement: the face assumes a ghastly hue, the jaw falls, the eye-lids remain half open, the pupils are strongly contracted, stupor and complete coma succeed; convulsions are rare in adults, but often are seen in infants. Adults in general die easy from this poison. Opium produces its fatal effect, however introduced into the system, and even when applied to a raw surface, has destroyed life. Morphia is stronger than opium, in the proportion of 1 to 6.

The principal morbid appearances are great turgescence of the vessels of the brain, and sometimes serous effusion between its membranes, or in its ventricles; the lungs are gorged with blood, the stomach rarely appears inflamed, the blood is found fluid in the heart, and the body runs rapidly to decay.

Evacuation by the stomach pump, or by emetics, is the remedy chiefly to be trusted; and after the patient is roused, we must prevent him falling asleep while any tendency to stupor is perceived. Artificial respiration appears to have saved one person who was found comatose. No antidote is known.

The best tests of crude opium are those which shew the presence of morphia and meconic acid. The contents of the stomach, in a case of the poisoning with opium, may have the smell of that drug. The whole should be emptied into a clean mortar, and reduced to a thin pulp by the addition of distilled water; acidulate the whole with acetic acid, strain and filter, then reduce the liquor to the consistence of a syrup by a gentle heat: add alcohol gradually, boil, and filter when cold. The spirituous solution will contain all the morphia. Again, evaporate to the consistence of syrup, and add magnesia, which will throw down meconate of magnesia and the morphia in the form of a greyish powder, which may be freed from much of its colouring matter, by washing it with cold water, and then with cold proof spirit. The morphia may now be separated from the meconate of magnesia by hot strong alcohol: concentrate this last solution, which will have a bitter taste, which, on adding a drop of nitric acid, will strike an orange yellow colour, soon passing to golden yellow; and will give a duck-blue with permuriate of iron.

The meconate should be decomposed by muriate of baryta, which will form an insoluble meconate of baryta; from which the addition of very diluted sulphuric acid separates the meconic acid. This acid has a silky lusture in the state of crystals, and affords, with permuriate of iron, a very intense red. There is only one source of fallacy in operating with meconic acid from the human stomach, which must be guarded against, namely, that the sulpho-cyanates of the alkalis precipitate permuriate of iron of a red colour, and some of the secretions, as the saliva contain a sulpho-cyanate. If the solution of morphia be strong there is no danger of mistake; because of the intensity of the colour produced. Professor Forbes has also shewn that the two solutions affect the prismatic spectrum in a different manner; though perhaps this test is less applicable to medico-legal causes, where the quantity of ingredients is generally very minute.

2. *Hyoscyamus niger*. The whole plant is narcotic, especially the roots, which have several times caused fatal effects, by being eaten instead of parsnips. The symptoms are active delirium, in which persons have danced and reeled about until stupor supervened. In persons fully under this stupor, stimuli cease to rouse, and the eye is insensible to light, or even to being touched. Emetics are the remedies; but we have no particular tests of this poison.

3. Besides Hyoscyamus, other *solaneæ* are narcotic. This is especially the case with *solanum nigrum* and *s. mammosum*. Both owe their activity to an alkaloid, *Solanea*; which is capable of exciting vomiting, hurried respiration and stupor. Forensic Medicine. Toxicology

4. *Lactuca virosa* is a poisonous plant, with a juice that is highly narcotic, and has the smell of opium. This juice, when inspissated, forms the *lactucarium* of the shops, which was at first derived from the *lactuca sativa*, but is obtained in greater quantity, and of precisely the same quality, from *l. virosa*. Stupor and coma follow an over-dose of lactucarium.

5. *Hydrocyanic acid*, or *Prussic acid* forms the poisonous ingredient in an important class of vegetables. It is yielded by the kernels of the *bitter almond*, and of several other species of that genus; by the leaves of the cherry laurel, or *prunus lauro-cerasus*, by the *prunus padus*; and probably is contained in the seeds of the *pomaceæ*, and in all vegetable productions with the odour of bitter almonds. The acid, when concentrated, is the most deadly of all poisons; producing almost instant death, whether swallowed or introduced by a wound. Even the diluted hydrocyanic acid of the apothecary's shop is fatal in a very moderate dose; and the essential oil of bitter almonds is not less so. An infusion of the leaves of cherry-laurel is a very deadly poison: bitter almonds have sometimes proved fatal; and the same effect has followed on eating the blossoms of the common peach, *prunus persica*, in a salad. When the preparation is concentrated, the death is very speedy: the breathing immediately becomes laborious, convulsive movements of the limbs come on; in dogs it ends in violent tetanus. After death the eyes are glistening, the pupils dilated, the muscles of the spinal column stiff, the countenance pale and often composed, the abdomen drawn in; the veins of the brain are found to be loaded with black blood, and the blood in the heart and great vessels is generally fluid. In some instances the blood and cavities of the body have exhaled a strong odour of prussic acid; and the blood has been said occasionally to have exhibited a bluish tint when the strong acid has been administered. The bile has often been observed to be of a dark blue hue in such cases.

No remedy can be of service in poisoning by this substance, unless instantly administered: but ammonia appears to have a great power in alleviating the symptoms when the quantity of hydrocyanic acid has not been very great. Ammonia diluted with water should be introduced into the stomach; its fumes sufficiently diluted with air allowed to enter the lungs, taking care not to excoriate the air passages by the too free use of the ammonia. Another very powerful antidote is chlorine. It is most advantageous to employ the vapour of water containing about one fourth part of its volume of chlorine gas. This may be inspired without risk; it has saved the lower animals when the poison had been administered for five minutes before its application, even after the convulsive stage had passed, and that of insensibility had supervened. In Orfila's experiments, in ten minutes after inspiring diluted chlorine in this manner, the recovery of the animals was certain. Herbst of Göttingen states, that dashing cold water on the surface of the body, is a powerful antidote in such cases: it is most successful *before* the convulsive stage, but is useful during the spasms.

The tests of hydrocyanic acid are certain when we can obtain it in quantity: but when we must look for it in the body, the smell is its best criterion. The stomach and the blood will sometimes have its peculiar odour for more than three days after death; and if the body has been buried within twenty-four hours, the odour will occasionally remain till the eighth day. When we can obtain a little of the liquid acid; nitrate of silver is a very delicate test. A white precipitate is formed, which, when dried and heated

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in a tube, gives off *cyanogene*, a gas that burns with a rose-coloured flame. If we add to the suspected liquid sulphate of copper, a rich emerald green solution is formed: and if to another portion of the liquor we previously add a drop or two of potassa, that test will throw down a greenish salt, which is partially dissolved by hydrochloric acid, leaving behind a cyanide of copper, which will yield cyanogene like the precipitate of silver. This test will detect prussic acid in 20,000 times its weight of water.

4. *Substances yielding strychnia.* The vegetable substances yielding this new alkaloid all act in nearly the same manner, and are very poisonous. The alkaloid was first obtained from the *strychnos nux vomica*, and *s. Ignatii*. One nearly similar in its properties is found in the bark of *brucea antidysenterica*, to which the name of *Brucina* has been given. This substance is likewise found in nux vomica united to strychnia. Both are highly poisonous, producing convulsions and tetanus; both are intensely bitter. Strychnia is used in paralysis, with advantage, in doses from one-eighth to one-fourth of a grain. Now that it is an officinal preparation, it may be employed as a poison; but there is too sure a substitute, in malicious hands, in the seeds of the two plants from which strychnia was first obtained. A dose of fifteen grains of the powder of nux vomica has been fatal.

The symptoms from this powder and from a much smaller dose of strychnia are similar. Spasms speedily ensue with anxiety and agitation, the limbs become stiff, the face and hands livid, from the impossibility of respiration, produced by the fixation of the muscles of the chest. These severe affections come on in paroxysms; the intervals exhibit nausea, a feeble pulse, and profuse perspiration: the repetition of the fits destroy life, and the victim seldom lives above an hour.

The best remedies, after evacuation of the stomach, appear to be the simple substances chlorine and iodine.

Where the death has been rapid there are little or no marks of inflammation to be seen in the stomach; but when it has been lingering, the stomach and intestines shew traces of violent inflammation; their colour is a violet, and incipient gangrene has been observed in some cases: serous effusion has been found in the head, the blood has remained fluid, and the body often retains, after death, the rigidity of the tetanus, in which the sufferer died; but in dogs poisoned by it the limbs are sometimes relaxed after death.

The powder of s. ignatii is stronger than that of s. nux vomica: both adhere obstinately to the villous coat of the stomach, and will generally be found there after death. They may be distinguished by their intense bitter taste, by becoming orange-red when nitric acid is added, a hue which soon passes to golden yellow.

The celebrated Javan poison is prepared from the *antiaris toxicaria* and *strychnos tieuté;* plants belonging to the natural order of the *Apocyneæ:* another plant of the same family, *cerbera tanghin*, is so deadly, that a single seed, it is said, will destroy twenty persons.

The *wourali* or *wourara* poison of South America is said to be derived from a *strychnos;* but this cannot be, if what Humboldt relates be correct, namely,—that the South American Indians use it as a purgative. We have found it fatal to animals in very minute quantity when inserted under the skin.

The bark of a South American tree has proved poisonous, when administered instead of true Angostura bark, *galipea officinalis*, or *bonplandia trifoliata.*

When we suspect any substance containing strychnia to be in the stomach, digest its contents with alcohol, and concentrate this tincture, which will be intensely bitter; precipitate by ammonia, and this precipitate, when a drop or two of nitric acid is added, will become orange-red if any strychnia be present.

5. *Tobacco* is a well known narcotic, of which the detection will be difficult, except by the smell.

6. *Atropa Belladona*, or deadly night shade, is a strong narcotic poison. All the plant is poisonous, especially the leaves and the fruit. The symptoms produced are delirium, dilated pupils, and loss of vision. Sometimes it causes hysterical bursts of laughter, the lips, tongue and throat are parched, there is a great sense of sinking, with tremulous movements of the hands; but convulsions are rare. Many instances of poisoning have happened from eating the berries and the young shoots. The active principles is an alkaloid, *Atropia.*

7. *Datura Stramonium* is another poison sometimes employed on the continent to facilitate robbery or rape; and in this country it has been administered by mistake. It owes its activity to an alkaloid, *daturia*, which abounds also in *d. tatula.* The extract of stramonium produces dryness of the fauces, intoxication and active delirium, with cerebral congestion.

8. Various *Umbelliferous plants* are poisonous; such as *conium maculatum*, *æthusa cynapium*, and *lactuca virosa.* The roots and leaves contain a poisonous juice, and the symptoms are those of narcotics, with some degree of irritation. Various authors have spoken of the *œnanthe crocata* as very poisonous; but Dr. Christison gave it largely to dogs, without killing them. *Conium maculatum* owes its activity to an oily alkaline principle, *conia;* which smells strongly of mice, and becomes, though a clear liquid when cold, opake on being heated.

9. Several of the *Ranunculaceæ* are acrid and narcotic, as the *ranunculus sceleratus*, *r. flammula*, *r. bulbosus*, *r. lingua*, *r. acris*, and *r. arvensis;* but we have no mode of detecting their poison.

10. *Aconitum napellus* produces delirium and stupor, with burning in the throat, vomiting, and purging.

11. *Helleborus niger* is a narcotico-acrid poison of great activity.

12. Several other poisonous plants may be mentioned, such as *anemone pulsatilla*, and *cytisus laburnum;* the seeds of the latter are narcotic. In all these cases the best remedies are emetics.

13. *Digitalis purpurea* owes its activity to *Digitalia*, an alkaloid, which may be obtained from it. The chief characteristic of digitalis is its extraordinary power in reducing the force and frequency of the pulse; on which account it is used in medicine, but it is poisonous even in small doses.

14. The other narcotico-acrid poisons of the vegetable kingdom we shall briefly notice, indicating such as have yielded alkaloids to analysis. Of these *menispermum cocculus* is one, the active principle of which is *picrotoxia: delphinium staphysagria*, the seeds of which yield *delphinia; chelidonium majus; arum maculatum; juniperus sabina; veratrum album*, which yields *veratria*, an alkaloid lately introduced as an external application, and nearly resembling another poisonous alkaloid, *colchicia*, obtained from *colchicum autumnale; bryonia alba*, said to afford *bryonina; euphorbia officinarum; hippomane mancinella;* various species of *jatropha*, which yet by cooking yield wholesome food; the seeds of *ricinus communis;* seeds of *croton tiglium; cucumis colocynthis; momordica elaterium; scilla maritima;* various species of *daphne;* several species of *rhus; hebradendron cambogioides; convolvulus jalapa*, and *c. scammonea.* To these some add *narcissus pseudo-narcissus*, *gratiola officinalis*, *caltha palustris*, and *lobelia inflata.*

15. *Poisonous Fungi.* Several of this natural order are poisonous, especially those belonging to the genera *Amanita* and *Agaricus.* Their poisonous qualities appear to de-

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pend on two principles; one of which is volatile, and disappears on boiling, drying, or macerating in a weak acid. To this principle Le Tellier ascribes the irritant quality of poisonous mushrooms. The other is not volatile, is soluble in water, unites with some acids into crystallizable compounds, and appears to be an alkaloid now termed *Fungia:* on this the narcotic properties of these plants depend. The time in which the symptoms occur, after the fungi have been eaten, is very various; often not until twelve or even twenty-four hours. The sufferers are often relieved by vomiting; but if not, the surface becomes livid and cold, violent colic ensues, and death is preceded by delirium and deep coma. The corpse is livid all over, the blood fluid, and sanguine discharges are apt to flow from the mouth, nose and eyes.

16. *Secale cornutum.* The *ergot of rye* produces, when eaten in bread, many of the symptoms of mushroom poison. Decandolle ascribes this disease of grain to a fungus of the genus *Sclerotium;* and it has been found to yield a principle resembling fungia. The tendency of this substance to produce dry gangrene is generally admitted by German and French writers. There is a learned dissertation on it by Dr. Wiggers, in which its fungoid origin, and its peculiar action in promoting the expulsive efforts of the gravid uterus, seem to be established.

17. *Alcohol and Ether* may be here considered, as being derived by art from vegetable matter. They are well known narcotics, producing at first intoxication, and afterwards stupor and cerebral congestion. They are also irritants, the stomach of persons killed by them being often inflamed. When the moderate use of spirit does not produce death, it may give rise to *delirium tremens.* The smell of spirit is often perceived in the cavities of the chest and abdomen of those who have died from drinking. The stomach-pump and milk are the best remedies.

18. *Camphor,* a concrete essential oil, has pretty strong narcotic qualities. It is best detected by its peculiar odour.

Animal poisons.

VII. Animal Poisons.

1. *Cantharides.* An acrid poison, is contained in the body of the *cantharis vesicatoria.* It is found to reside in a whitish matter, resembling spermaceti in colour and consistence, which is united to three other marked principles. The first is a green oil, soluble in spirit, but not in water; the second a blackish matter, soluble in water, not in spirit; the third a yellowish viscid matter, soluble both in water and in spirit. This last is united in the insect with *Cantharidine,* and renders it soluble in water, which it is not when pure.

The symptoms of poisoning by cantharides are, intense burning heat in the primæ viæ, painful deglutition, pain in the stomach and bowels, bloody vomiting, painful micturition, and priapism, intense desire to void urine, and distressing pain in the whole urinary organs; frightful convulsions and tetanic spasms usher in the fatal termination. When the flies in substance have been swallowed, the fragments of their green *elytra* are found adhering to the villous coat of the stomach; and this has been observed even after the body has been buried for months. There is no antidote for this poison. Evacuants and mucilages are the best remedies. Oil given by the mouth increases the evil, by dissolving the cantharadine, but oil thrown into the bladder is useful in allaying the irritation.

2. *Fish Poison.*—This singular subject is little understood, except that, in certain seas, and in certain seasons, fishes, at other times wholesome, prove deadly poisons. This is chiefly the case with the *yellow-billed sprat,* the *barracuta,* the *grey snapper,* the *sparus venenosus,* and *grey labrus* of the West Indies; with several species of *diodon* and *tetrodon,* and with *aplodactylus punctatus,* of the Southern Ocean. The rapidity and fatality of the poison has been described by Chisholm, Ferguson, and Thomas. The symptoms are, irritation in the throat, tingling of the surface, burning heat in the stomach and bowels, colic, nausea, spasms, giddiness, coma, and death. It is said that persons have died whilst masticating a portion of the fish, ere any of it was swallowed. The juice of the sugar cane, and various sweet liqueurs, are said to be useful in the slighter cases.

Fishes in this country are sometimes poisonous; and muscles have occasionally, with us, produced death, with less rapidity, but with symptoms of the same kind. The cause of the poisonous quality of fish is, with some probability, attributed to their having fed on acrid mollusca.

The flesh of birds is occasionally poisonous; as happens to the *phasinanidæ* of North America, when they have fed on the buds of the *kalmia latifolia.* The honey of the bee, in like manner, is poisonous, when they have fed on the sugar of the *rhododendron* and *kalmia,* as is described by Xenophon, Pallas, and Dr. Smith Barton. In the former case the honey produced a species of madness; in the latter, the symptoms were similar to what occurred to the soldiers of Xenophon.

3. *Animals have a poison generated in them by disease,* which is capable of infecting those who eat, or even touch their flesh. The best known instances of this is in the *pestis bovilla* or *murrain* among domestic animals, by which their flesh and juices become deadly poison to other animals. This appears somewhat analogous to the accidents that happen in dissection.

4. *The bites of rabid animals* belong to the same class of poisons. The bite, for instance, of a rabid dog, will destroy other animals; after some time they become delirious, then paralytic, and invariably die rabid. In man similar symptoms occur, to which is superadded hydrophobia;—a symptom never observed by Mr. Youatt in any animal except *man.* Excision of the wound, or destruction of the part by caustic, is the best prophylactic; belladona and scutellaria lateriflora seem to have some preventive power, according to the same authority; and excessive bleeding seems to have arrested or cured the disease in India.

5. *Bites of Snakes.*—Poisonous snakes are provided with two or more teeth placed on a moveable bone, on each side of the upper jaw, and corresponding to the maxillary bones of other animals. These teeth or fangs are hollow, and have their roots connected with a duct, that conveys the poison from a bag placed under the principal muscles that close the jaws; so that when the animal bites, the poison is squeezed from the bag, and is instilled, through the hollow of the fangs, into the wound. The symptoms, in general, are in proportion to the quantity of the poison, compared to the size of the animal bitten, the smallest animals suffering most. The general symptoms are, pain in the part wounded, trembling, weakened respiration and circulation, and coma. The most poisonous snakes are the *rattle-snake* of America, and the *cobra de capello* of India; the *viper* of this country and of France sometimes produces fatal accidents. Excision of the part, sucking, or cupping the wound are to be tried; and both ammonia and arsenic given internally appear to have considerable power in curing the bites, even of the most deadly snakes.

6. *The stings and bites of Arachnidæ and Insecta,* are poisons of a similar kind. The complex apparatus of the sting of the bee and wasp convey poison to the wound, so acrid, that horses, asses, and also men, have died from numerous stings. The sting of the scorpion, and bite of *scolopendra morsitans,* as well as of spiders, are inflicted with a poisoned apparatus analogous in structure to the fangs of snakes.

Imaginary Poisonings

VIII. Imaginary, Pretended, and Imputed Poi-

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sonings, require much patience and attention on the part of the medical jurist; to them no general rule can be applied, but they must be treated according to the nature of each particular case.

PART II.—MEDICAL POLICE.

SECTION I.—CIRCUMSTANCES AFFECTING THE HEALTH OF INDIVIDUALS.

Cleanliness.

I. Cleanliness.—This subject may be considered under three heads.

1. *Personal cleanliness* is valued by all nations in proportion to their advance in civilization, and exercises an important influence on the health of individuals. Most savage nations are disgustingly deficient in this virtue; but the polished nations of antiquity paid great attention to it, as is evinced by their general use of baths, the stupendous ruins of which still surprise us in the remains of their cities. In modern times, especially in Great Britain, warm and cold bathing are far less employed than is desirable; and we cannot help regretting the want of public baths for all ranks, especially in our manufacturing towns, where the luxury of warm or tepid bathing might be very cheaply obtained, by collecting the waste water from the *condensing backs* of steam engines. Bathing, by removing sordes and remains of perspiration, keeps the skin in a fit state for its important functions. Public baths should be established in every town, and all children should be taught to swim. The warm and vapour baths of northern Europe prove how cheaply such luxuries might be obtained for the great mass of the community.

2. *Domestic cleanliness* is perhaps better understood by the Dutch and the English than by any other nations in the world. This virtue has been long practised in Holland, but is comparatively only of late origin in Britain. The picture which Erasmus draws of English manners is not very flattering; and our own historians prove that it was not until after the civil wars of the 17th century that the English became a cleanly people. Now no nation can surpass them in domestic cleanliness, and none equal them in domestic comfort. The effect on the health of the inhabitants is shewn by the less frequent attacks of severe epidemic diseases in modern times, and perhaps also by the increased value of life annuities.

3. *Ventilation of Habitations* is one important part of domestic economy, now better understood; and Strutt, Sylvester, and Murray have taught us how ventilation may be combined with warmth. The renewal of the air, vitiated by respiration and combustion, is secured by simple contrivances, and the air admitted into apartments is warmed by passing between a close stove or cockle and an exterior covering.

Aliment.

II. Aliment.—Under this head may be considered,

1. *Preparation of Food.* Alimentary matters are rendered more wholesome and nutritive by cooking; and the mystery of that art is not unworthy of consideration, even were it not also the means of economizing the sustenance, and increasing the gratification of man.

2. *Culinary Utensils* deserve attention here, because the wholesomeness of aliment often is materially affected by them. There is risk of cooking food, especially of the acescent or oleaginous kinds, in copper vessels, though the danger is diminished by keeping the utensils always bright, and not suffering the food to remain in them after removal from the fire. Vessels of lead and pewter should be entirely banished from the kitchen, as they are never without danger, from the ease with which they are acted on by acids. Tinning copper vessels renders them safe, as long as the coating of tin lasts; but the vessels usually made of pewter, an alloy that contains lead, should be replaced by those of block tin, or of tinned iron. The objection to the last kind of vessels is their little durability, and the lead solder with which they are put together. Vessels of iron are durable and cheap, but they blacken some kinds of food: this is best obviated by a coating of tin. Vessels of gold and silver are far too expensive for ordinary use; but copper is often covered with a thin plate of silver, forming what is termed plated ware, which is excellent while the silver remains on the copper. A thinner coat of silver is applied, in some instances, by means of an amalgam of silver, and a similar process is commonly used to gild the inside of silver or of plated ware. *Pottery* is a valuable addition to culinary utensils. It is of all qualities, from the purest porcelain of China or of Europe, to the coarsest earthenware. The glazes which contain lead are objectionable, where acids are to be used, but if well baked, such glazes are not readily acted on. For chemical experiments the porcelain of China or of Germany, in which there is no lead, is always preferred, and it would be so also for culinary purposes, but for the expense. These glazes are made with felspar, or with mixtures of flint and alkalis.

3. *Adulterations of Food* may be accidental or designed. We have just stated how lead and copper may find their way into food, but there are other accidental adulterations. Farina, or flour, may be rendered unwholesome by the presence of the *ergot*, the *smut* of wheat, and the seeds of *lolium temulentum*, which last act as a narcotic. Flour may also be mixed with sand, from the use of too soft millstones; with other impurities, from want of care in winnowing or grinding; or by fraudulent mixtures of chalk and gypsum. Bread may be mixed with chalk, magnesia, potassa, soda, or alum, to conceal bad flour; and it has been sometimes adulterated with white lead. These adulterations are easily detected. On rubbing down the bread into a pulp with water, the heavy particles will subside to the bottom, and may be collected; the alum, alkalis, or lead may be detected by chemical tests. Butcher meat may be unwholesome from disease in the animal, or by long keeping. Butter may be deteriorated by containing too much salt or water. Water may be unwholesome or disagreeable from corrupting animal or vegetable matter; from being too hard, that is, containing too much saline or earthy ingredients. Soft water may be adulterated by passing through leaden pipes, or standing in cisterns of that metal. Milk may be fraudulently mixed with water, or with magnesia and chalk. Malt liquors have been purposely adulterated by *cocculus indicus*, *lolium temulentum*, &c., to increase their intoxicating qualities. Wines have been chiefly adulterated by brandy, to give them strength; by preparations of lead, to correct acidity, and impart astringency. This last ingredient is best detected by a test, consisting of a solution of tartaric acid, impregnated with sulphuretted hydrogen. The chief adulterations of spirit are by water, which is detected by the hydrometer; and by lead, accidentally introduced from the worms of the stills. Lead is readily thrown down by infusion of galls, which will convert new unwholesome spirits into good spirit. Vinegar is liable to contain lead and copper, from the pipes and cocks through which it flows. These metals are easily detected by sulphuretted hydrogen and ammonia.

Police of drug-shops

III. Police of Apothecaries Shops.—The supply of good drugs is regulated, in many countries, by the government. Inspectors are appointed, who examine and report on the state of the drugs found in the premises of dealers, and any infringement of the laws is rigorously punished. In our country the inspections are a mere form, of little or no utility. They should be made by persons paid by the state, and competent to the task, whose office should be honourable.

Clothing.

IV. Clothing.—The importance of paying attention to

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the qualities of clothing is generally admitted. The advantage of flannel or cotton next the skin, to persons of a consumptive habit, or of otherwise delicate constitutions, and also to soldiers and sailors, or other persons whose occupations are laborious, is acknowledged. The use of linen next the skin is suitable for the young and robust; but as persons advance in life, cotton or woollen under-garments are advisable.

1. The *Male dress* should afford sufficient protection to the parts it covers, and should not impede the free use of the limbs. The covering of the head should defend the eyes from excess of light, and the head from the sun. Any thing tight about the neck is injurious. Those who take much exercise will find useful support from broad belts round the waist; especially as they advance in life.

2. The *Female dress* should keep the body comfortably warm. Compression of the chest and abdomen of females is far too general; and the ribs of most of our ladies are deformed by tight lacing. This practice diminishes the cavity of the chest; it confines the stomach and liver excessively, and has a tendency to contract the width of the pelvis. By the first, consumptive diseases are induced; by the second, the function of digestion is injured; by the last, the perils of child-bed are increased. The practice of tight-lacing is ancient. It is severely stigmatized by Juvenal; and is condemned by all modern authors. Excessive exposure of the bust is also too general among women, and often lays the foundation of disease.

Temperance.

V. Temperance.—Its importance to health, to vigorous youth, and to honoured age, need not be insisted on. Gluttony is not less destructive, and is even more disgusting than drunkenness: both are sure to end in debasement of the mental faculties, and destruction of the bodily health.

Exercise.

VI. Exercise.—Regular exercise in the open air is highly conducive to health; and those who are interested in the improvement and happiness of the lower classes in our towns cannot help lamenting the little that has been done to encourage our artizans and shop-keepers to take out-door exercise in pure air.

The philanthropist must remark with regret the circumscription of the means of enjoying fresh air, which the enclosure of commons and of waste lands, near towns and villages, has produced, and the discouragement, by officious magistrates, of the out-door games and pastimes of the lower orders. Part of the sums, so frequently left to endow hospitals and alms-houses, would be more rationally expended on gymnasia for the encouragement of healthy sports in the open air, or on public walks for the recreation of our citizens.

Prostitution.

VII. Prostitution.—In most parts of the Continent the state has interfered, not, as is falsely alleged by some, to raise a revenue from this polluted source, but to secure the rising generation, as much as possible, against the fearful consequences of diseases, that sap the foundations of a nation's strength, by impairing the sources of a healthy progeny. The unfortunate class of females, who may generally be considered as the victims of male licentiousness, are there regularly registered, and subject to domiciliary visits of the authorities, who send them to hospitals, when disease first makes its appearance. The arguments against this practice are not more rational than it would be to forbid the medical practitioner to lend his aid in other cases, where the imprudence of the sufferer was the cause of his malady.

Celebacy and marriage.

VIII. Celibacy and Marriage.—In the most polished states of antiquity marriage was enjoined by positive enactments, and enforced by penal statutes; in modern times legislators wisely leave it to the sense and discretion of individuals. In fact the propensity to celibacy is so small in most persons, that marriage may be safely entrusted to individual will. The tendency to increase and multiply is so forcible that it will generally be found to produce a population up to the very limit of the means of providing for children. It was for advocating this philosophical truth, and for pointing out the natural checks to a redundant, and miserable, because destitute, population, that Malthus has been abused by sciolists and pretended philanthropists, who appear, from their senseless declamations, either never to have read his works, or not to have comprehended their import.

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Lactation.

IX. Lactation and Care of Offspring.—The important duty of rearing the helpless infant devolves by nature on the female parent; and in general it can never be so well performed by any other individual. In an artificial state of society, however, many females become mothers who are not able to nurse their children. In such cases we would recommend the employment of a wet nurse, as affording the best chance of rearing the infant. The child should not be long fed *exclusively* from the breast; because its stomach should be gradually accustomed to other food before it is weaned. The infant is totally dependent on the care of those around for its preservation. To retain it healthy, it should undergo daily ablutions, have its clothes of suitable warmth, easy, and frequently changed. Its food should be chiefly of milk and farinaceous matter for the first two or three years. It should have regular exercise in the open air; and not be confined in its early years to too sedentary occupations. The dreadful mortality in foundling hospitals proves the importance of the circumstances alluded to under this head.

Profession and trade.

X. Effects of Profession and Trade on Health. This is a very important consideration, and may be divided into various heads.

1. *Diseases incident to affluent idleness* are chiefly such as arise from indolence and want of some definite object of pursuit; hypochondriasis, tedium vitæ, dyspepsia, gout. For these the best remedies are, rural amusements, intellectual pursuits, mingled with sufficient inducements to take exercise in the open air.

2. *Diseases of Literary Men* are chiefly produced by want of attention to regular exercise in the open air, giving rise to dyspepsia and constipation; by inequalities in the time of eating and sleeping; and by excessive use of the eyes in artificial light. They are best obviated by abridging the hours of study, and mingling sedentary avocations with active and social occupations. Literary men, however, especially in France, have been a long-lived race.

3. *Clergymen* have a wholesome intermixture of sedentary with active duties; and, if their lungs be sound, they are generally long-lived.

4. *Lawyers*, when their occupations are chiefly at the desk, are subject to the diseases of sedentary persons; but barristers, when not excessively harassed by toil, may generally be considered as engaged in a healthy occupation. Many of our judges attain extreme old age.

5. *Medical Men*, from the general activity of their pursuits, their knowledge of the causes that promote health, and the wholesome exercise of mind and body induced by their profession, are generally considered as a long-lived class: but in this, as in other learned professions, small account is made of those who die before they have become known, of those who pine away from penury and hope deferred, or whom a desire to better their condition sends abroad to perish on inhospitable or pestilential shores. Yet taking the whole together, the medical profession is certainly favourable to longevity.

6. *Schoolmasters, Clerks, &c.* are subject to the usual diseases of sedentary persons, and to those produced by passing a great part of the day in vitiated air, with the sternum leaning on a desk. Such persons should live at some distance from the scene of their labours, that they may be compelled to take exercise in the open air

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7. These observations apply also to *Merchants*, to *Master-manufacturers*, and *Shop-keepers*. A British merchant has, when successful, an enviable life. The morning is dedicated to business, and the afternoon to his family and friends; while his home is usually remote from the crowded streets, in which his counting-house is necessarily placed.

8. *The shopman*, however, generally leads a very different life. He is late and early in the shop, the whole day is spent in serving customers, and in many instances his hours of rest are abridged by the duties of his business, which afford him no time to take exercise in the open air. This is peculiarly hard on young persons, perhaps sent from the country to be immersed in the smoky atmosphere of a crowded, narrow street. Multitudes of both sexes annually fall victims to this change.

9. *Soldiers and Sailors*, when they escape the perils of training to their laborious occupations, are often healthy, if temperate, and if care be taken of their health by their superiors. Their ailments often arise from their own intemperance, as much as from the casualties of their calling. Excessive fatigue is certainly unfavourable to longevity; and when we find very old persons in this class, we may attribute it in a great measure to the iron nature of constitutions, which have enabled them to resist the hardships to which they must have been subjected in their younger years. Soldiers on duty are more exposed than sailors to wet and cold, to unwholesome climates, and to bad fare. A sailor carries with him his provisions and his change of raiment; and in the British navy he has much attention paid to his health while on board his ship. Long marches are apt to produce diseases of the hip joint, and hernia, especially in young soldiers. The sailor is liable also to hernia from strains in the course of his laborious duty.

10. *Agricultural Labourers* have generally a very healthy occupation, when the returns of their industry afford them sufficient aliment and comfortable clothing. Their situation is much more favourable to health than that of the town-mechanic. The same may be said of carters, postilions, and coachmen; except that the latter are often exposed at night to the inclemencies of the weather, and are not always remarkable for sobriety.

11. *Quarrymen and Stone-masons* are liable to serious injury, from the minute dust they create entering the air passages along with their breath. This often gives rise to a species of consumption; and such persons are seldom long-lived. It affects the stone masons of Scotland more than those of England: the former work under sheds, the latter in the open air. Marble-cutters for the same reason are unhealthy; and even the employment of a sculptor cannot be considered as a good one for a person of delicate lungs.

12. *Carpenters* and *Joiners* exercise healthy trades, because they require activity, and are freely exposed to the air in many of their operations. It is very different, however, with artizans whose trades are chiefly carried on in a vitiated atmosphere.

13. The trade of the *Weaver* is always rather unhealthy from his working in a confined space; but the introduction of machinery has reduced the pittance of the hand-loom weaver below what can support life with any comfort, and his habitation is proportionally wretched. There is in this occupation exercise to the limbs; but the breast leans against the beam, which, with wretched fare and depressed spirits, render the trade of the weaver unfavourable to health.

14. *Milliners and Tailors* are confined in hot, and ill-ventilated rooms, they work too many hours in the day, and often have the natural hours of rest greatly abridged. Milliners are liable to become short-sighted, and the practice of biting the thread generally injures their front teeth. The lives of young females are often sacrificed to this business. Tailors assume a faulty position whilst at work; and the consequence is, that when they walk, they nave a peculiar strut; the increased power imparted to the muscles of the back, from long supporting the weight of the head, causes the shoulders to be preternaturally drawn back. They are also very subject to phthisis. Medical Police.

15. *Shoemakers* are more healthy; but the pressure of the *last* against the sternum and stomach is sometimes injurious.

16. *Miners and Well-sinkers* are engaged in laborious trades, in which they are exposed for considerable periods to breathe a vitiated atmosphere; and are further liable to the bad effects of inhaling dust, which predisposes to asthma.

17. Artizans working amidst *putrid animal matters* seem more liable to plague and typhoid fevers than most other classes.

18. Artizans exposed to inhale *minute particles of dust* are very liable to pectoral diseases. This is especially the case with knife and needle grinders. They are subject to the disease called *grinder's rot*, an incurable consumption, which renders this occupation most deadly. Currents of air, and interposed plates of glass, have been used to remedy which evil. Large magnets have been employed to arrest the iron dust, but it cannot abate that from the grindstone itself, which is not less fatal.

19. *Workers in lead, brass, and copper*, are subject to disease, from those substances finding their way into the system, as already stated.

20. *Bleachers and Dyers* are liable to suffer from acrid fumes, in some instances, and also from sudden changes of temperature.

21. *Snuff Makers and Millers* are exposed to dust; and the former to the consequences of inhaling also a narcotic; but the effect is seldom very marked on either.

22. *Chimney Sweepers* are liable to consumption, and to a peculiar cutaneous disease, the *chimney sweeper's cancer*, which chiefly affects the scrotum. Early excision removes it; but it is liable to recur.

23. *Cotton, silk, and flax spinning* by machinery expose the operatives to bad air, dust, and confinement in hot rooms. This is especially injurious to the young, who are much employed, from eight years and upwards, in such manufactories. The hours of work of all classes in them are too long. Woollen factories seem to be less unhealthy on the whole; but in them the employment of very young children, and too long hours of labour, are to be regretted.

24. *Persons exposed to a high temperature*, such as *Cooks*, *Confectioners*, *Bakers*, are liable to rheumatism, from sudden changes of temperature. Bakers were remarked to be the most general victims of the plague, at Marseilles, in the beginning of the last century. *Sugar-refiners* are exposed to much heat, and to sudden chills. *Smelters of iron*, and other ores, are subject to the same; to cough, from dust, especially if they be founders; and their eyes become weak, from he intense glare of the metal. *Glass-blowers* not only suffer from these causes, but also from the excessive exertions of their lungs, which often give rise to hæmoptysis and asthma.

SECTION II.—CIRCUMSTANCES AFFECTING THE HEALTH OF COMMUNITIES.

Climate.

I. Climate.—The effect of climate, the most general of these circumstances, depends chiefly on the temperature, the hygrometric state of the air, and the general force and direction of the winds. The temperature of any place is well known to depend, in a great degree, on its latitude. The inclination of the earth's axis to the plane of its orbit has diffused the influence of the sun's rays more extensively over the surface than if the same points had always a ver-

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tical sun. The changes in temperature had been marked long before there was an instrument for measuring their extent, and hence the distribution of the earth's surface into parallel zones denominated *climates;* but the invention of the thermometer shewed how ill this arrangement accorded with observation; and it was soon found that there were very different climates under the same parallels. The average or mean temperature is obtained by a series of thermometrical observations, carried on in the open air, and in the shade. Large springs and deep caverns usually have the mean temperature of the place where they occur; and it has been found that a series of observations made every hour through April, will give a pretty accurate mean temperature of that place for the whole year.

Temperature, however, is also considerably modified by longitude. Thus it is found that the mean temperature of any latitude in western Europe is higher than that of the corresponding latitude in eastern Asia, or in America, as may be seen by casting the eye over Humboldt's chart of isothermal lines. A comparison of similar observations indicated to Sir David Brewster that there were, in each continent, certain meridians on which the mean temperature is the lowest in that parallel. These he termed the *cold meridians,* in approaching to which the mean temperature falls on either hand.

But the principal circumstance which modifies the effect of latitude is elevation above the sea. As we ascend mountains, the temperature falls; and in every region, if its mountains be sufficiently lofty, they are the abodes of perpetual congelation. The limit varies with the latitude: it is highest under the equator, and diminishes as we approach the poles: thus, at the equator, the point of perpetual congelation is more than 15,000 feet above the sea; in Britain it is about 5000. The climate of a place, then, varies with the latitude, with the longitude, and with the elevation.

Even when the mean temperature is the same, places may differ greatly in the extremes of heat and cold in summer and in winter. The chief agent in equalizing heat is the ocean, the temperature of the mass of which remains nearly the same in all latitudes. This renders the summers of islands less hot, and their winters less cold, than that of continents under the same parallels. The peculiarities of climate affect the vegetable productions of a country, and its salubrity is greatly modified by the nature of its surface. A region shrouded in forests is generally colder than one exposed to the rays of the sun; and the exhalations from swamps and marshes materially affect its fitness as a residence for man. Such countries are subject to violent intermittent and remittent fevers, especially when the marshes are acted on by intense solar heat; and in tropical regions such places are pestilential. Several other diseases appear to depend on climate, as the *goitres* and *cretinism* of the Alps, and other mountainous countries, the elephantiasis of Africa and the West Indies, and the strumous affections of cold climates.

All these peculiarities must be considered by those consulted on,

The sites of towns.

II. The Sites for Towns and Habitations.—If the medical man be asked to give an opinion on any particular site, let him consider,

1. *The purity and hygrometric state of the air.*—The average proportions of the cognizable ingredients of atmospheric air are,

	Measure.	Weight.
Nitrogen, ...	77.50	75.55
Oxygen, ...	20.00	23.32
Carbonic acid, . .	0.08	0.10
Aqueous vapour, . .	1.42	1.03

The proportions of the gaseous ingredients are nearly the same everywhere; but the proportion of aqueous vapour varies greatly, according to the temperature and pressure of the atmosphere. It is the source of clouds, dew, fog, and rain, according to the suddenness of its precipitation. The quantity present in air may be estimated by Leslie's *hygrometer.* The quantity of rain which falls in any place should be ascertained by the *rain gauge;* and the quickness of evaporation by experiment, or by observations with Leslie's *atmometer.* The number of rainy days should also be noted; for the quantity of rain is not proportional to the number of wet days. In hot climates it rains more seldom, but more falls than in temperate regions. Thus, the mean annual rain in the West Indies averages 120 inches; at Calcutta it is=81; at Rome=39; at Liverpool=32; at Edinburgh=24; at Petersburgh=16. In any climate, more rain in mountainous districts than in plains. Thus, 50 inches fall in Argyleshire, whilst at Glasgow the rain is about=30; at Elgin=24 inches.

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The changes in barometric pressure should also be noted. These are extremely small within the tropics, or even in southern Europe, but fluctuate in northern Europe even to $\frac{1}{10}^{th}$ of the whole column

2. *A supply of potable Water* is a most essential requisite. It should not be *hard,* it should be free of any peculiar taste or smell; and the nearer its specific gravity approaches 10002, to distilled water as 10000, so much the better. The capability of carrying water through pipes, to any station, is important, when a colony is to be founded. Running water of a good quality is also very important; but it should be recollected that stagnant water is not wholesome.

3. *Fuel* is another essential requisite, both for cooking and for warmth. A plentiful supply of wood, coal, or peat is indispensable where many human beings are to be congregated. Open fire-places are cheerful, but not economical modes of warming apartments; stoves are more frugal; hot-air-flues combine ventilation with warmth, but require considerable attention in their management; steam-tubes convey an equable temperature, but are less convenient than the circulation of hot water, in the apparatus devised by Mr. Perkins.

4. *Vicinity of Trees* is an important circumstance; but it must not be forgotten that a station buried in deep forests is seldom wholesome, and in hot climates is often pestilential.

5. *Vicinity of Hills and Mountains* is also deserving of consideration. If they be very lofty, in hot climates, the plains at their feet are often pestilential, producing *black vomit* and *jungle fever;* yet removal to the mountains immediately relieves the sufferer, as is witnessed in the ascent from Vera Cruz to Xalapa, and from southern Hindustan to the Neilgherries.

6. *Vicinity of Marshes,* in every country, is to be shunned, in fixing on a site for human habitations. Marshes produce malignant remittents in hot seasons, and give rise to severe hepatic disease. The marsh fevers of Walchern, and the *malaria* of Italy, originate in stagnant water; and the fatality of some of our stations in the West and East Indies are to be attributed to swamps. Some of them, as British Guiana, have become more healthy as the country is more drained and cultivated.

7. *Vicinity of the Sea* is always an important element in choosing a station. In hot climates the sea-breeze mitigates the heat of day, and renders it endurable. This breeze, in summer, is very regular even at Gibraltar. The vicinity of the sea also mitigates the cold of winter. Sometimes it renders a station unhealthy, when the recession of the tide exposes a great extent of a muddy beach. This is especially the case at the mouths of great rivers; yet such stations, though unwholesome, are often politically important, as naval stations, or as keys to the back-country. Marshes, into which sea-water occasionally enters, are observed to be more pestilential than mere fresh-water swamps.

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Drains and sewers.

III. Drains and Sewers are important public works, on the proper construction of which the salubrity of a station may greatly depend. They should have such a fall as to carry off impurities, and to prevent an accumulation of stagnant water. The Greeks and Romans excelled in their attention to such works; but the unhealthiness of many places in Italy, in the present day, is owing to the neglect of those useful structures.

Public ways.

IV. Paving of Streets, and Care of Public Ways, are objects also worthy of the attention of the medical man, though chiefly in the province of the civil engineer.

Cemeteries.

V. Cemeteries.—Little attention has been, in this part of Europe, bestowed on the police of repositories for the dead. Burial in churchyards, in the midst of a crowded population, and even within churches, is still suffered to disgrace our cities. The French have set a good example; and the Turks have been long noted for the decent propriety, and judicious position of their cemeteries, which are always beyond their towns. The same is the practice of the Chinese, and of many nations whom we call barbarous. A better system is commencing among us, in the new cemeteries of Glasgow, Liverpool, and a few other places; and it is fervently to be hoped, that ere long our towns will cease to be infected with putrid emanations from crowded churchyards, and the temple of God to be polluted with the frail remains of mortality. The cemeteries of London are a disgrace to the metropolis: they are rather better at Edinburgh; but the cemeteries ought to have been removed altogether beyond the city; and the retired valley between Salisbury Craig and Arthur's Seat, offers an admirable site for a spacious and magnificent necropolis. The best mode of sepulture is probably in the earth, without vaults; but anything is preferable to the horrid practice in Rome, of disposing of the carcases of the poor in huge caverns, often opening into the very churches.

Hospitals.

VI. Hospitals.—The erection of hospitals is intimately connected with the subject of medical police. We cannot enter on a consideration of each sort of hospital, but state in general terms, that the wards should be lofty, with windows on one side, and galleries on the other for exercise to convalescents. Ventilation should be secured by some of the means already indicated; the wards should be provided with privies, and baths appropriated to each; the bedsteads should be of iron, as less liable to harbour vermin; airing grounds and convalescent rooms should be attached to all hospitals. In a lunatic asylum, each class of patients should have separate airing grounds; and occupations suited to their cases should be provided for convalescents. Foundling hospitals, from the mortality in them, even under the best management, seem to be amongst the most pestilent institutions of mistaken benevolence. Such considerations induced a German author to propose as an appropriate inscription over the gates of such establishments, "Children murdered here at the public expense." Hospitals for the sick, military hospitals, and barracks, all may fall under medical police.

Schools.

VII. Schools.—Seminaries for the instruction of youth merit more attention from the legislature than they have received. The rooms are often defective in ventilation; and the modes of warming them in cold weather are often very inefficient. In some schools too little attention is paid to vary the diet of children; and though seldom deficient in quantity, at large public and private schools, there often exists inattention to render it palatable, or to suit it to peculiarities of constitution. In many schools the hours of study, for very young children, are too long. The degrading practice of public flogging, even almost to manhood, in some schools, is brutalizing to the inflictor, and destructive of the delicate sensibilities of ingenuous youth. We must also stamp with our strongest disapprobation the practice of *fagging*, which prevails at some English schools, and is calculated to foster the vices of both tyrants and slaves. In female seminaries the lessons are generally too long, the pupils too sedentary, too little in the open air; and many female *accomplishments*, as they are termed, are apt to produce lateral curvature of the spine, as was fully proved by the late Mr. Shaw.

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Prisons.

VIII. Prisons.—The state of our prisons is much improved since the time of Howard. The principal improvements are in the county prisons of England, in many of which much attention is paid to preserving the health of prisoners, by clean rooms, commodious airing grounds, and humane regard to their diet, and the cleanliness of their persons. In most of the prisons of this country, however, much is still defective, in what relates to the classification of prisoners, and separating juvenile delinquents from hardened offenders. In the county jails of Lancashire and Cheshire, much has been done to render prisons what they ought to be; but even in some of the best English prisons there are still no hospitals for the sick inmates; and the jails of Scotland are far behind those of the two counties alluded to in every respect. As far as lodging and diet go, there is no room for improvement in many British jails; and this humane attention is rewarded by the disappearance of jail-fever from our island. The subject of prison discipline is a wide field. The benevolent exertions of Mrs. Fry and her Quaker associates prove, that much good would flow from attention to the instruction and moral improvement of the unhappy inmates of our prisons.

Lazzarettos.

IX. Lazzarettos and Quarantine Establishments are of Italian origin, at the period when the commerce of the East was engrossed by the free cities of Italy. The doctrine of contagion is not of modern origin, as has been ignorantly alleged. Notwithstanding the clamour of interested individuals, a few years ago, no rational medical man denies the contagious nature of the plague; and we have no doubt that the immunity of this island from that dreadful scourge, for 170 years, notwithstanding our multiplied relations with the East, is mainly owing to the rigour with which the quarantine laws have been enforced. Some of these regulations may err on the side of excess of caution; but this is far preferable to rash experiments, prompted by crude medical speculations, and supported, as they were attempted to be, by distortion of facts. The quarantine laws were revised in 1825, and the code is now, upon the whole, good. The quarantine stations for Britain are Standgate-creek, Deal, Milford-haven, Liverpool, Holyloch in the Clyde, and Inverkeithing bay in the Forth.

Punishments.

X. Punishments.—This subject, the last of the present dissertation, is worthy of the attention of the legislator and of the medical jurist.

1. *Corporal Punishments*, inflicted by sentences of our courts, extend to imprisonment, whipping, and forced labour.

Imprisonment is adjudged for several offences, and even for inability to pay a debt. When the health of a prisoner might suffer from confinement in a damp or unwholesome jail, the humanity of judges has frequently mitigated the severity of the sentence, on the representations of medical witnesses. It would be unjust to inflict a greater punishment than the law contemplated, by the mode of confinement; but in general our jails are far more comfortable, as far as lodging and diet are concerned, than the usual habitations of the very poor; and therefore imprisonment, in some instances, may have lost some of its salutary terrors in preventing crime.

Whipping is sometimes inflicted by sentence of the court, either publicly or privately; it is now generally applied to juvenile offenders in prison, and is far less frequently inflicted in public than formerly, especially since the abolition of the pillory for ordinary crimes. Flogging is still permitted to a limited extent both in our army and the navy. A medical man is always by on such occasions; and should he declare

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the punishment *enough*, even one lash more, at that time inflicted, is a crime, and would subject the officer who ordered it to indictment for murder, should the sufferer die. *Hard labour* is now generally inflicted by the *tread-mill*, a contrivance by which the united weight of the prisoners condemned to it puts in motion a wheel, which moves machinery. The defect of this punishment is its inequality. To active persons, accustomed to walking, it is a light exercise; but to sedentary persons it is a most grievous punishment, giving intolerable pain to the muscles of the legs and the spine. To the disgrace of our country, it has been inflicted on females. Their muscles are too weak, and their habits little inured to such labour; and it is liable to induce *prolapsus uteri*, or miscarriage, if the prisoner be pregnant; or serious diseases of the female system, in various ailments of the sex. It arms, too, with a dangerous and tyrannical power ignorant justices and unfeeling magistrates. The law should forbid this infliction on females in all cases, and prevent the erection of tread-mills in all prisons not liable to the legal inspection of grand juries; which it seems *houses of correction* in England are not, they being "not under the jurisdiction of the sheriff of a county." The beating of hemp was formerly with us the infliction for petty crimes; and in Holland it was rasping of dye-woods in the *Rasphaus*, which was always considered as a severe punishment. In America the penitentiary system of forced labour has been tried, and is still a subject of discussion. Solitary confinement has also been employed there; which some have considered worse than death.

2. *Capital punishments.*—In this country, excepting in cases of nobles for treason, *hanging* is invariably the mode employed by law. This is with justice preferred to any other mode of public execution, as the evidence of those, who have recovered after suspension, renders it probable that the person suffers very little pain, from his becoming speedily insensible; and when the *drop* is employed, the injury to the neck seems generally to extinguish life instantaneously.

Beheading is in this country performed with the axe, in Germany with the sword, and in France with the guillotine; the prototype of which seems to be the Scottish *maiden*, still to be seen in the Antiquarian Society's Museum in Edinburgh. The axe often requires a repetition of the blow; and the sword is liable to the same objection. The maiden chopped off the head by the descent of an axe loaded with lead. The guillotine slices it off, entering one side of the neck by an oblique edge. All sorts of beheading present a very ghastly spectacle, and habituate to the sight of human blood; besides which, serious doubts have been started as to the possibility of the head for a short time retaining its sensibility.

3. *Pleas in bar of execution.*—When a person is condemned to die, execution of the sentence may be deferred on three pleas.

Insanity may be pleaded by the relatives of the condemned, and a jury may be appointed to try the sanity or insanity of the prisoner.

The *youth* of the party is the second. There is no age fixed by British law, at which the perpetrator may not be executed for heinous crimes. In 1629 a child between eight and nine years of age was executed in England for an atrocious murder; one of ten years was condemned in 1748 at York; and a boy of thirteen was executed in this city, within the present century, for a murder. Blackstone states the lowest degree of non-age, by the practice of the English courts, to be seven years.

Pregnancy is the last plea admitted in our courts. When this is alleged, a jury of matrons is appointed by the judge to inspect the party, and if the allegation be found true, she is respited till after delivery. These persons are very incompetent to so delicate a task. It should be entrusted to accoucheurs, who, from the appearance of the mammæ, and the application of the stethoscope to the abdomen in the latter months, will readily ascertain the truth or falsehood of the allegation. (J. J. J.)

MEDICINE.

Medicine, in its most extended signification, may be said to comprehend all the knowledge which can be useful in enabling us to prevent the occurrence of diseases; or which may assist us, when diseases have occurred, in conducting their treatment, with a view to their alleviation or cure. The knowledge subservient to these several purposes (the prevention, alleviation, and cure of diseases) may be comprehended under three general heads: 1st, an acquaintance with the human economy in the state of health;—2d, an acquaintance with the various deviations from the healthy state, or, in other words, the various diseased, morbid, or pathological conditions to which that economy is liable;—and 3d, an acquaintance with those agents or powers which are capable of inducing disease in the economy, when it is in a healthy condition, and with those which are capable, when it is in a diseased condition, of restoring it to a state of health; that is, an acquaintance with what are termed morbific causes and therapeutic agents.

It is necessary to consider medicine both as a science and as an art. To the *science* of medicine it belongs to collect all the facts that have been ascertained respecting the operations and phenomena of the economy in its healthy and morbid conditions, and respecting the causes and remedies of diseases; to compare these facts with one another, so as to discover their mutual relations; to arrange them in a convenient order, and to deduce from them the general conclusions to which they may seem to lead; and to point out where the knowledge of facts is imperfect, and to suggest the means by which such deficiencies may be supplied. The *art* of medicine, again, consists in the immediate practical application of the knowledge that has been acquired by observation and experiment, in the several departments enumerated, to the prevention and treatment of diseases.

In the following article it is proposed in the first place to take a brief view of medical science considered in reference to the three departments which medicine has been said to comprehend. A similar view will afterwards be taken of those divisions which convenience and custom have established in medicine considered as a practical art. It is in the susceptibility of the economy to be affected with diseases, and in the influence which certain circumstances and agents exercise in producing their removal, that medicine, both as a science and as an art, has its primary origin. Diseases and their remedies, accordingly, must have been the first subjects of medical investigation that engaged the attention of mankind. The importance of a correct acquaintance with the human economy in a state of health could

Health. come to be felt only after these practical branches had made some degree of advancement. It is now, however, well understood that the extent of knowledge which can be acquired respecting the human economy in the state of disease, must in a great measure be dependent upon the knowledge that is possessed of that economy in the state of health; since the very ground-work on which all rational inquiries respecting diseases must ultimately rest, is the knowledge of the circumstances in which the economy that is disordered, differs from the same economy in a sound condition.

Health. I. As the human economy consists of two distinct elements, an organised body and a conscious mind, which, whatever may be the nature of their connection, exercise most important influences on one another; and as both of these elements of the economy are liable to experience deviations from their natural or healthy condition, a knowledge of the body and of the mind, in the healthy exercise of their functions, forms the essential foundation of medical science.

The study of the *mind*, in its healthy condition, has usually been regarded as constituting a particular department of philosophy (psychology) quite independent of medicine; but we shall afterwards find reason for believing that the consideration of its various phenomena, intellectual and moral, ought to be included under the same department of medical science that treats of the healthy phenomena of the corporeal part of the economy.

The knowledge of the *organised body*, in the state of health, is of a two-fold nature; *first*, as it relates to the structure of its several parts; and, *secondly*, as it relates to the use, purpose, or function which each part performs in the economy, and to the reciprocal dependence of the different functions on one another. The two branches of medical science that treat of the structure and functions of the body, are comprehended, as every one knows, under the names of Anatomy and Physiology; branches which are, no doubt, most closely allied, and in some respects inseparably connected with one another, but which are at the same time sufficiently distinct in their objects and in their means of prosecution, and sufficiently extensive in the field of investigation which each of them presents, to admit of, or rather to require, separate consideration in any view of them pretending to be systematic.

Anatomy. To each part of the body capable of performing some particular function or purpose in the human economy, the name of *organ* is usually assigned; thus the eye is said to be the organ of vision; the stomach and intestines with the liver, pancreas, &c., the organs of digestion; and the muscles, bones and joints, the organs of voluntary motion. In examining the structure of the different organs of the body, it is found that they all consist of different anatomical elements; and whilst some of these elements vary in the different organs that are examined, others of them are met with in all the organs indiscriminately. Thus if we compare the structure of the heart and of the liver, we shall find in the former, layers of muscular fibres of which no trace can be observed in the latter organ; while in the liver, on the other hand, we find a peculiar arrangement of cellular matter, usually denominated parenchyma, to which nothing analogous is discoverable in the heart. In both of these organs, however, vessels, for the conveyance of blood and other fluids, and nervous filaments can be discovered; and these latter anatomical elements, the vessels and nerves, pervade, in greater or less number, all parts of the animal frame. Whilst each bone and each muscle may be said, in some sort, to have a separate existence, independent of every other bone or muscle of the body, every blood-vessel and every nerve, on the contrary, exists only as a part of a general system, all the ramifications of which are connected with one another through the medium of a central organ or part. Those anatomical elements which vary in the different organs of the body, such as muscular fibre, cellular substance, mucous and serous membrane, &c., are denominated *textures* by anatomists; whilst those which are constant in all the organs, the blood-vessels, lymphatics, and nerves, are regarded as parts of their corresponding *systems*. Health.

Its several departments. There are several different points of view in which the structure of the human body may be considered. 1st, We may examine the different classes of organs and the different systems, separately, confining our attention principally to the relations which the different organs of the same class, or the different parts of the same system bear to one another; the bones, the muscles, the vascular system, the nervous system, &c., each being treated of under a distinct head. It is in this view chiefly that the structure of the body is considered in what has been termed Descriptive Anatomy. 2nd, We may consider the relations which the different organs and systems entering into the composition of any particular region of the body, bear to one another, as, for example, the relations of the muscles, blood-vessels, and nerves of the neck; or the relations of the parts of the perineum to one another and to the lower part of the bladder. It is this kind of anatomical knowledge, (the anatomy of the regions, as it has been termed), which is essential in the performance of surgical operations, and which has hence frequently received the name of Surgical Anatomy. 3d, We may examine into the minute structure of each of the different kinds of organs and parts of systems, as of the stomach, liver, heart, arteries, brain, nerves, &c., and endeavour to ascertain in relation to each, whether it consists of one or of several elementary substances or textures, what is the physical arrangement of each of the textures entering into its composition, and in what manner these are united and combined. To this minute investigation of the structure of the different organs and systems of the body, and of the textures entering into their composition, the name of General Anatomy has been assigned. 4th, We may compare the different parts of the human frame, as the nervous or vascular system, the respiratory or digestive organs, &c., with the corresponding parts of other animals, a comparison which frequently leads to an improvement and extension of our knowledge of the structure of the human body. To this field of inquiry the name of Comparative Anatomy has been given. And, 5th, We may enquire into the progressive development which the body and each of its parts undergoes, during the embryo and fœtal states, from its earliest period of formation to the time of birth; a branch of investigation which has received the name of the Anatomy of Development, and which is equally applicable to man and to the lower animals.

When we reflect on the length of time during which the structure of the human body has been the subject of investigation, the number of persons who have been engaged in the inquiry, and the enthusiasm with which it has been prosecuted, it may appear strange that there should be still many anatomical points respecting which we are aware that our knowledge is very deficient; and that from time to time facts are brought to light, in this department, of which no previous suspicion had been entertained. Anatomical discoveries, as appears from the foregoing observations, may relate to the textures, to the systems, to the organs, or to the regions of the human body; or they may relate to the structure of the lower animals, or to the gradual development of animal bodies during their fœtal existence.

1. The anatomy of *textures* is comparatively a recent investigation, for though it cannot be said to have originated with Bichat, yet unquestionably it received from him the dignity of a separate branch of scientific inquiry; not only from his having contributed materially to its advancement by his own labours, but from his having by the ingenious and philosophical views which he took of the subject, rendered the medical profession more fully aware of the important ad-

Health. vantages to be derived from its cultivation. But besides being of recent origin, the anatomy of textures is a subject attended with very considerable difficulties from the minuteness of the objects to be investigated. As illustrating these difficulties, we may refer to the various statements which have at different times been given respecting the primary structure of muscular fibre, of bone, and of nervous substance. And as the principal means by which we are assisted in overcoming them, may be mentioned in the first place, the employment of chemical re-agents, by which, in some instances the parts are rendered more fit for examination by being hardened, as is, for example, the case with the substance of the brain; and in other instances the structure of the part is ascertained by one texture being destroyed whilst another is left entire, as in the case of the bones and nerves. As a second means of overcoming the difficulties attendant on the anatomical investigation of textures, may be mentioned the use of the magnifying glass and of the microscope. The latter instrument, which was invented about 1620, seems to have been first applied to purposes of anatomical investigation by Malpighi, who was followed in this line of research by Hook, Power, Leuenhoeck, and Lieberkuhn. In later times it has become an essential part of the apparatus of the anatomist.

2. The discoveries relative to the anatomical *systems*, which have from time to time been made, and which may be expected to be still further extended, refer to the minute ramifications of the vessels and of the nerves; to the modes in which the different kinds of vessels, arteries, veins, capillaries, and lymphatics communicate with one another; and to the connections of the minute filaments arising from different nerves. The prosecution of this department of anatomy, in particular, has been most materially advanced by the invention of the art of injections. "In the latter part of the last century," says Dr. Hunter, in his introductory lectures to his last course of anatomy, "this science made two great steps, by the invention of injections, and the method of what we commonly call preparations. These two modern arts have really been of infinite use to anatomy; and besides, have introduced an elegance into our administrations which in former times could not have been supposed to be possible. They arose in Holland under Swammerdam and Ruysch, and afterwards in England under Cowper, St. Andre, and others, where they have been greatly improved. And from England, they are of late years spreading to all parts of the British dominions, to France, Italy, and other parts of Europe. I say, *from England*, because the arts of making fine injections and preparations seem to have been almost peculiar to Holland and England, and the anatomists who have excelled in that way have generally made a secret of their methods and improvements, till within the last thirty years, when all these arts have been constantly taught in public courses of anatomy *here*."

3. The anatomy of the *organs*, and particularly of some of the internal viscera, as the brain, the liver, &c., notwithstanding the repeated investigation to which they have been subjected, still presents an extensive field of inquiry; for much remains to be ascertained as to the textures that enter into the composition of each organ, and as to the relations of these textures to one another, and to the ramifications of the systems with which they are more or less largely combined.

4. In the anatomy of *regions*, the objects of investigation are on comparatively a large scale, and consequently more easily discovered and appreciated. Yet structural arrangements modifying the progress of surgical diseases, and regulating the performance of surgical operations, still continue from time to time to be brought to light. The improved knowledge that is at present possessed of the anatomy of the parts concerned in hernia, and in the operations of aneurism and of lithotomy, bears honourable testimony to the diligence and skill with which this department has in modern times been prosecuted. Health.

5. *Comparative* anatomy, though from the name it bears, it obviously originated in the comparison of the structure of the human body with that of other animals, has in its progress come to form a science in itself; and when we consider the number of animals already known, the additions that are from time to time made to these, by those who are engaged in exploring distant regions of the globe, and the increased facilities of obtaining specimens for the purposes of dissection, afforded by voyages of commercial or scientific enterprise, it is not wonderful that this department should every day be presenting a rich harvest of discovery to reward the industry of those who are engaged in its cultivation.

6. The anatomy of *development*, notwithstanding the zeal with which it has, in modern times particularly, been cultivated, still affords an extensive field for the collection of curious and interesting facts. From the ease with which observations may be made on the eggs of birds, during the progress of incubation, many anatomists have availed themselves of the opportunity thus afforded for studying the development of the fœtus and its several organs. But it was not till a very late period that their observation was extended to the formation or evolution of the organs in the other classes of vertebrated animals. It is satisfactory to know that the more the structure of the ova of the different classes of vertebrated animals has been studied, the more perfect has the resemblance between them appeared to be. "Since our acquaintance with the development of the ovum has increased," says a late writer on this subject, "the mode in which the organs of the fœtus are produced, has been proved to be analogous in the different classes of vertebrated animals; and we are induced to believe that a knowledge of the simpler forms of these animals must greatly facilitate our study of the more complicated." We may remark that there are two leading views, in conformity with one or other of which the investigation of this department of anatomy has been prosecuted. According to the one view, the impregnated ovum, or original germ, before the process of development has commenced, contains already formed all the parts which are afterwards to be found in the perfect animal; so that the successive appearance of the organs of the animal, which is observed during the progress of development, is owing simply to the evolution, or coming into sight, of parts which had previously been invisible, in consequence of their small size and of their transparency. According to the other view, the original germ, before development has commenced, is very simple in its structure, and does not, so far as can with the greatest attention be discovered, contain any part that can be compared to the fœtal or adult animal, so that during the development of the fœtus, its organs are actually formed, and not simply evolved. Those who entertain this opinion accordingly maintain, that several of the organs of the embryo can be seen gradually forming by the apposition of their parts. Closely allied with the anatomy of development is the inquiry relative to the various malformations or monstrosities which animal bodies occasionally exhibit; for according to the notion that may be adopted respecting the primitive condition of the germ, and the changes which it subsequently undergoes, will be the view entertained as to whether the occurrence of monstrosities is attributable to some peculiarity in its original structure, or to some imperfection or irregularity in its development. And in proportion as our knowledge shall be extended, of the relative periods at which the different organs are formed, and of the successive series of changes which they undergo, will we be the better able to analyse and comprehend the modes in which monstrosities are produced.

Besides the consideration of the functions of the corpo- Physiology.

Health. real part of the economy, Physiology comprehends likewise, as has been already hinted, that of the phenomena of mind. All these phenomena, or operations of the human economy, corporeal and mental, it has been found convenient to arrange under three classes of functions, designated by Galen, the Natural, the Vital, and the Animal. Under the *Natural* are included those functions which are performed by all organised beings, plants as well as animals, and which are essential to the preservation of the individual, and the continuance of the species; the functions, namely, of nutrition and reproduction. The *Vital* class of functions comprehends two, which, in the higher orders of animals at least, cannot be suspended for more than a very short space of time, without putting a stop to life; the functions of circulation and respiration. The *Animal* functions are those by the exercise of which the animal creation is particularly characterized, but which vary in their degree and perfection, according to the place the animal occupies in the scale of existence; the functions of sensation, thought, and volition.

On an analysis of all the phenomena which these several functions exhibit, it will be found that these phenomena are of three kinds. In the production of some, corporeal organs only are concerned; others are wholly of a mental character; and others, again, are partly mental and partly corporeal. The corporeal operations of the human economy, as regards their *results*, are physical or chemical, that is, they consist in changes in the relative situation of sensible particles, unattended with change in their composition; as when the blood is conveyed from the heart throughout the whole fabric of the body, and again returned to the central organ of circulation: or they consist in changes in the combinations and arrangements of elementary particles; as in those changes of deterioration and purification which the blood undergoes during its progress through the greater or systemic, and the lesser or pulmonic circulation. There are several operations of the economy, of which the present state of our knowledge does not enable us to determine whether they be properly of a physical or of a chemical character; as, for example, those processes by which various fluids are separated from the blood, in the different organs of secretion. As regards their *causes*, the corporeal phenomena of the animal economy seem to be partly dependent on the common properties of inorganic matter, as gravity, weight, elasticity, chemical affinity, &c.; and partly on vital properties peculiar to animal bodies, more particularly the irritability of the muscular fibre, and the energetory influence of the ganglionic system of nerves.

With respect to the phenomena of the human economy that are wholly mental, "there is," as was well observed by the late Dr. Thomas Brown, "a physiology of the mind as there is a physiology of the body; a science which examines the phenomena of our spiritual part simply as phenomena, and from the order of their succession, or other circumstances of analogy, arranges them in classes under certain general names; as in the physiology of our corporeal part, we consider the phenomena of a different kind which the body exhibits, and reduce all the diversities of these under the names of a few general functions." A knowledge of the intellectual and moral powers, though their investigation forms the peculiar province of the metaphysician and moral philosopher, is essentially necessary to the physiologist, both from their own importance as parts of the constitution of man, and from the powerful influence which they exercise over his bodily functions. It is obvious, likewise, that a knowledge of the mind in its healthy exercise must be equally necessary to a proper understanding of mental diseases, as is a knowledge of the body in the state of health to the understanding of *its* diseases. It is gratifying, therefore, to find that medical men are becoming more and more aware of the importance of acquiring such a knowledge of the operations of the intellectual faculties and moral feelings as may serve as a groundwork for the scientific study and humane treatment of mental diseases. The most interesting point of view, certainly, in which the mental phenomena present themselves to the consideration of the physiologist, is in their connection with the nervous system. It is well known that while some physiologists are content with recognising a general connection between the faculties of the mind and the brain, others have endeavoured to establish a more especial relation between particular mental powers and particular parts of the cerebral organ. Health.

Of the phenomena of the economy in the production of which the mind and body are both obviously concerned, a part, those, namely, of sensation, originate in the body and are concluded in the mind; whilst another part, those, namely, of voluntary motion, originate in the mind, and are concluded in the body. In each of these two functions, the nerves seem to serve as the medium of communication between the brain, as the more immediate organ of the mind, and the different sensory and motory organs of the animal frame.

Its sources of improvement.

The progress of physiology is necessarily dependent on the advancement of other collateral sciences, particularly of anatomy and of chemistry, as well as on experimental research. A few illustrations of the advantages that have accrued to physiology from the improved and extended cultivation of each of these departments, may serve to place this dependence in a clear point of view.

1. As to the influence of anatomy on the advancement of physiology, we may observe, that to know the action or operation of a machine, it is essential to know its mechanism or structure; and to those conversant with this kind of inquiry, nothing in many instances is requisite but a knowledge of the relative situation and the connection of parts, to enable them to comprehend the general effect which will result from their combined action, and the particular share which each part contributes towards its production. There can be no doubt that the circumstance which first directed the attention of the illustrious Harvey to those investigations which terminated in the discovery of the circulation of the blood, the most important physiological discovery certainly that has ever been made, was his desire to ascertain the use of the valves of the veins, the existence of which had been pointed out to him by his distinguished teacher in anatomy, Fabricius ab Aquapendente. It is obvious, too, how great a difference in the knowledge possessed of the function of assimilation must have been produced by the discovery of those absorbent vessels, the lacteals, as they have been termed, that convey the digested food or chyle from the intestinal canal along the mesentery, to the common trunk named the thoracic duct, which ultimately discharges it into the venous system. It was not till 1622 that the lacteal vessels were discovered by Gaspard Aselli at Cremona, and twenty-five years elapsed subsequently to this before Pecquet of Dieppe discovered, at Montpellier, the thoracic duct. Previously to that time it had been supposed that the chyle is conveyed by the veins of the mesentery from the intestines to the liver, and that it is the peculiar function of this organ to convert that fluid into blood.

2. Many illustrations might be given of the lights which chemical science has in modern times thrown upon the phenomena and functions of the animal economy. The reciprocal changes which the atmospheric air and the blood produce upon one another within the lungs, in respiration; the changes which the food undergoes from the action of the different fluids with which it comes in contact in its passage through the alimentary canal; and the composition of the different products of secretion, as the gastric juice, the bile, and the urine, are amongst the more remarkable objects of physiological inquiry, to the advancement of the knowledge of which chemistry has powerfully contributed.

3. Every function of the body furnishes a host of in-

Health. ‖ Disease.

stances in which our knowledge of its mode of performance and of its reciprocal dependence upon, and influence over, the other functions, has been advanced by experimental researches. None of these researches, perhaps, are more important in the conclusions to which they have led and still promise to lead, or have been prosecuted with greater diligence and sagacity, than those which relate to the dependence of particular functions upon particular portions of the nervous system.

Disease.

II. Such, then, are the two points of view in which it is necessary for the purposes of medical science to consider the human economy in the state of health; *first*, in relation to the structure of the body and its several parts; and *second*, in relation to the actions or functions of these parts, or the corporeal and mental phenomena of which the human economy is the field of operation. But it is in precisely the same points of view that it is necessary for us to consider the economy in the state of disease. There is a department of Morbid as well as of Healthy Anatomy, and a department of Morbid, as there is one of Healthy Physiology. These two departments considered separately, and in their relations to one another, constitute the branch of medical science denominated Pathology. As it is the object of Healthy Anatomy to make us acquainted with the structure, forms, dimensions, and connections of the several textures, systems, and organs of the body, in the state of health; so it is the object of Morbid or Pathological Anatomy to make us acquainted with the changes in all of these respects, to which the different parts of the body are liable in the state of disease. And in like manner, as it is the object of Healthy Physiology to make us acquainted with all the several phenomena, corporeal and mental, that are taking place in the human economy in its healthy condition, to trace the causes from which they originate, the mechanism by which they are accomplished, and their reciprocal dependence and influence on one another; so it is the object of Morbid or Pathological Physiology to ascertain to what deviations the several corporeal and mental phenomena are subject in the state of disease, and to discover what new phenomena are developed in that state, and by what powers or agents these deviations are occasioned.

Morbid Anatomy.

No department of medical science, probably, ever received so large an accession of materials for its elucidation, in so short a period of time, as morbid anatomy has done, since medical men became fully aware of the benefit which Theoretical and Practical Medicine is capable of receiving from the investigation of those various morbid alterations of structure that occur in the different organs of the human body. There are three principal points of view in which the knowledge obtained by necroscopical examinations may be considered; and were we to trace the history of Pathological Anatomy, it would be easy to shew that the consideration of that knowledge in these different points of view, marks the successive epochs in the progress of this department of medical science.

Its successive epochs.

1. Pathologists may endeavour to ascertain the various morbid alterations that occur in the structure of the different textures, systems, and organs of the body, in the progress of particular diseases, as of fevers and febrile eruptions, of tetanus or locked jaw, or of consumption, &c. The *Observationes Medicæ Rariores* of Schenckius, published at Frankfort in 1600; the *Sepulchretum sive Anatomia Practica ex Cadaveribus morbo denatis* of Bonetus, published at Geneva in 1679; and the *Epistolæ de Sedibus et Causis Morborum per Anatomen indagatis* of Morgagni, published at Venice in 1761, though differing widely from one another in importance and merit, may be regarded as all belonging to this first period of Pathological Anatomy, seeing that they all consist, for the most part, of individual cases of disease, arranged in a systematic order according to the part of the body which had been principally affected.

Disease.

2. They may consider each particular texture, system, or organ of the body, (as, for example, serous membrane, the heart and blood-vessels, or the stomach and intestines), separately, and without reference to individual cases of disease, in relation to the various morbid changes of structure which it is liable to undergo, (such as inflammation and its consequences, morbid degenerations and new growths,—and with a view to the effects which these changes produce on the performance of the functions of the particular texture, system or organ. As illustrations of this mode of considering Morbid Anatomy we may refer to the systematic works of Ludwig, Baillie, Conradi, Voigtel, and Otto. The recent investigations respecting the morbid alterations of structure that occur in the different portions of the nervous system, in the heart and blood-vessels and in the organs of respiration, are most creditable proofs of the diligence and success with which this department has been prosecuted in the course of the present century.

3. They may consider each particular kind of morbid structural change, (as inflammation, tubercle, cancer, &c.), as a separate subject of examination, in respect of the general characters which it exhibits from its first development till its termination or the death of the individual, in all the parts of the body in which it is liable to occur, and the modifications it exhibits in each particular texture or organ. It is by the greater degree of attention bestowed upon this department, that the pathological anatomy of the present day is more particularly distinguished from that of former times. But though great additions have recently been made to our knowledge of morbid structures, as for example, in what relates to the development of tubercle, by the works of Bayle, Laennec, and their followers; to the distinctions between scirrhus and fungus hæmatodes, or hard and soft cancer, by the writings of Hey, Burns, and Wardrop; and to the existence of morbid structures not previously known, such as melanosis; a great deal still remains to be accomplished before this branch of medical science can be considered as placed upon a satisfactory footing.

Its means of advancement.

The means by which our knowledge of morbid structure has been extended, and may be expected to be still further advanced, are the same as those upon which the progress of healthy anatomy depends; frequent dissection of the dead body, and the employment of those physical and chemical aids to which we had formerly occasion to refer.

A circumstance which has materially assisted in diffusing a knowledge of the morbid alterations of structure which the different textures, systems, and organs of the body are liable to undergo, has been the formation in anatomical museums, of collections of specimens of diseased parts. These collections seem to have consisted at first, chiefly or solely, of such substances as could be preserved in a dry condition, such as macerated bones, calculi, &c.; but their value has been greatly increased in later times, by the collectors availing themselves of the art of making wet preparations. Within a still more recent period an important advancement has been made in the application of the pictorial art to the illustration of pathological anatomy. It is long indeed since it has been customary to represent in engravings, detached specimens of diseased parts, particularly of those which exhibit considerable change of form on the external surface of the body; and some valuable works had been published, in which particular branches of pathological anatomy had been considerably advanced by illustrations of this description. The "Series of Engravings, intended to illustrate the Morbid Anatomy of some of the most important parts of the human body," which was published by Dr. Baillie at the beginning of the present century, is alike distinguished by the sound judgment displayed in the selection of the subjects, and by fidelity and beauty in their representation. But it has been of late years only that pathologists have called in the aid of colouring to assist in

Disease. conveying an idea of the changes which disease induces, not only on the surface of the body, but in each of its different textures, systems, and organs. And when it is considered how important an element colour forms in the characters by which the different morbid alterations of structure are distinguished, and how seldom it is possible to preserve any traces of it in preparations, it must be obvious how much coloured delineations are calculated to aid in communicating a knowledge of pathological anatomy, by conveying to the mind, speedily and precisely, through the medium of the eye, appearances of which the most lengthened verbal descriptions can enable the reader or hearer to form only a very imperfect conception.[1]

Of the light which the improved knowledge of morbid alterations of structure has thrown upon diseases and their treatment, we shall afterwards have occasion to speak; at present we may remark, that as morbid anatomy has been promoted by the gradually improving acquaintance with the anatomy and physiology of the body in the state of health, it has in its turn materially assisted in elucidating many obscure and difficult points in these two departments of medical science. The processes of disease, indeed, not unfrequently fulfil the same purposes as the experimental measures to which anatomists and physiologists are wont to have recourse, in prosecuting their respective investigations. Of this many striking illustrations might be found in the injuries and diseases of the different portions of the nervous system.

Pathological chemistry. As an important ally of pathological anatomy, in the investigation of disease, it is proper to mention pathological chemistry, or the application of the knowledge that has been acquired, respecting the composition of the different solids and fluids of the body, to the discovery of the morbid changes which they are liable to undergo. Our knowledge of the results of morbid action has already received very considerable and valuable additions through the means of this department of scientific research. Amongst the benefits for which we are indebted to it, may be mentioned the replacement of the vague and conjectural art of Uromancy, by a body of precise information relative to the various morbid changes which the urinary secretion experiences in the diseases of its own peculiar organs, or in those of other parts of the body.

Signification of the term Symptom. Before proceeding further in this general view of that department of medical science which relates to disease, it may be proper briefly to state the import of two terms of which we shall have frequent occasion to make use, namely, symptom and proximate cause, and to point out the principal varieties of symptoms and proximate causes, as they present themselves to the consideration of the pathologist. By a *symptom*, then, is meant any phenomenon or circumstance which leads us to infer that some one or other of the functions of the economy is not exercised in its ordinary or healthy manner. Of these circumstances a knowledge may be acquired in three ways: 1st, through the information of the patient; 2d, by direct observation; or, 3d, by experimental investigation. Of each of these modes of recognizing or discovering symptoms, we shall offer a few illustrations.

1. We know that a person in health sees objects single, and does not experience any sensations of sound unless his ear be exposed to atmospheric vibrations. But if a patient tells us that he sees objects double, and has ringing in his ears, these we hold to be symptoms of derangement in the exercise of the sensory functions of the nervous system. It is only by the information of the patient himself that we can obtain a knowledge of the occurrence of these and similar symptoms, having a relation to the exercise of the function of sensation. Disease.

2. In a person in health, the colour of the skin exhibits a peculiar hue, known by the name of flesh-colour; and the two sides of the face are nearly or altogether symmetrical. But if the skin assume an orange yellow, or a scarlet hue; or if one side of the face is drawn over to the other, so as to give to it a twisted appearance, these unusual phenomena lead us to conclude that some parts of the economy are out of order; they serve us as symptoms of disease, and are obviously examples of that class of symptoms a knowledge of which we acquire by direct observation.

3. We know that in a healthy person the temperature of the surface of the body is about 97° Fahr., and that the frequency of the strokes of the pulse ranges within certain limits, corresponding with the age of the individual. If by trial or experiment we find that the temperature has risen above or fallen below the standard of health, or that the frequency of the pulse either exceeds or falls below the limits proper to the period of life, these deviations furnish so many symptoms of disease. Again, the fluid secreted by the kidneys, besides exhibiting certain physical characters obvious to the sight, has been found by experimental examination to possess a determinate specific gravity, and to contain certain chemical elements in determinate proportions. These, however, are subject to variations in the state of disease; and the ascertainment of these deviations by appropriate instruments, and by the employment of chemical tests and processes, furnishes us with important aids in detecting the existence of diseases, and in determining their nature. To the same class of symptoms, also, we must refer those which are furnished by the practices of percussion and auscultation; practices that have turned the attention of physiologists and pathologists to so many curious circumstances respecting the healthy and morbid actions of the body, particularly those of the organs of circulation and respiration.

It must be remembered, however, that there exists a considerable latitude in the mode in which the functions are naturally exercised in different individuals; and therefore that what may justly be accounted a symptom of disease in one individual, may in another be perfectly consistent with the state of health. The whole external appearances of different individuals, as their complexions, degree of corpulency, and of muscular vigour, furnish numerous illustrations of diversities in the exercise of the functions, compatible with health. The degree of ruddiness or of sallowness, of corpulence or leanness, of strength or feebleness, which would mark disease in one individual, may be said to form a part of the natural constitution of another. In the same way, though there be a general correspondence in the frequency of the pulse of persons about the same period of life, yet exceptions are by no means unfrequent, so that the pulse of an individual in health may beat as quickly as that of another in a state of fever, or as slowly as that of a third person labouring under some affection capable of diminishing the frequency of the heart's contractions.

Proximate cause. By the term *proximate cause*, again, as employed in me-

[1] Professor Lordat of Montpellier, in his *Essai sur l'Iconologie Médicale, ou sur les Rapports d'utilité entre l'art du Dessin et l'étude de la Médécine* (1833), has given a brief but interesting outline of the connection which has subsisted between anatomy and the fine arts, particularly painting and engraving, in the successive periods of their progress; and has with great justice represented the art of engraving as having most powerfully contributed to advance the knowledge of anatomy. M. Lordat has thrown out some ingenious reflections, too, on the applicability of painting to the representation of what may be called the physiognomy of disease; that is, the changes it produces on the outward appearance of the frame. He does not, however, seem to have even dropped an incidental allusion to the applicability of delineation to the illustration and advancement of pathological anatomy. The advantage that might result from the application of coloured delineations to the representation of diseases was fully pointed out by Professor Delius, in his *Meditatio de Iconibus Pathologico-Anatomicis ad Naturam pictis*, published at Erlangen in 1782, along with his treatise *De Chlolelithis*, in which he gives a coloured plate representing gall-stones.

Disease. dicine, is understood that morbid deviation from the healthy state of the economy, to which the morbid phenomena or symptoms of a disease are ultimately referable, the morbid condition or pathological state on which their occurrence depends; the conditions of the body, for example, in the cases of the symptoms adverted to, to which the double vision, the ringing in the ears, the yellow skin, the twisted face, and the increased heat or the frequency of pulse, are respectively attributable. Thus understood, proximate causes admit of being arranged under two principal heads. 1st, those in which there is an apparent change in the structure of some portion of the organised frame, as in scirrhus and cancer of the gullet, stomach, or intestines; 2d, those in which no appreciable change of structure can be detected, as in dyspepsia or indigestion, and some forms of dysphagia or difficult deglutition. If we follow out this division of the proximate causes of diseases into the *organic* and the *functional*, we find that the organic may be subdivided into those in which the parts naturally existing in the body are altered in their structure, and those in which an entirely new substance is produced. Thus inflammation produces various alterations in the structure of the lungs; but in pulmonary consumption a number of small bodies called tubercles are scattered through them, which form no part of their original substance. The functional proximate causes, again, seem referable to three classes; those in which the action of the diseased organ is increased, those in which it is diminished, and those in which it is otherwise vitiated or perverted. The secretion of the kidney, for example, may be in excess of quantity, as in the disease termed diabetes; or it may be below the natural standard, or entirely suppressed, as in ischuria; or this secretion may want some of the ingredients which it usually contains, or contain some that are not usually found in it, as in some species of gravel. It is of importance to keep in mind, that when there occurs in the economy such a deviation from the state of health as to constitute disease, it seldom happens that only one proximate cause exists; but that there may be several different morbid conditions, and these even in different parts of the body, concurring to produce a particular disease. It must be kept in mind, also, that for the most part each proximate cause existing in the body gives rise not to one single but to several morbid phenomena or symptoms.

If we consider what idea we can form of any individual disease, such as pulmonary consumption or gravel, there appear to be two different conceptions which we may entertain. 1st, We may associate mentally that group of external phenomena, or symptoms as they are called, by which we are made aware that certain inward changes, not directly appreciable by the senses, have occurred in the organic system of our patients. Thus, in speaking of pulmonary consumption, it is the cough and expectoration, the gradual emaciation and debility, with alternations of feverish chilliness and flushings, which enter into our conceptions, as constituting or representing the disease. In speaking of gravel, it is the pains experienced in the region of the kidneys, and extending thence along the urinary passages and the parts sympathising with them, together with the appearance of crystalline or lateritious matter in the urine, which suggest themselves to our minds. But in the second place, we may form our conception of a disease from the alteration of structure or of function in which we suppose it essentially to consist; from that morbid condition or pathological state, in which the diseased economy differs from the healthy, the proximate cause of those external phenomena which we designate as symptoms. Thus pulmonary consumption, according to this view, we consider as consisting in the deposition of tubercles in the substance of the lungs, and in the series of changes which they undergo, or to which they give rise in the surrounding textures. Gravel we consider as consisting in a morbid action of the kidneys, in consequence of which the proportions of the constituents of the urinary secretion, are not duly balanced.

Disease. According to the former of these views then, a disease consists in a determinate group of symptoms observed to occur, in combination or succession, in a number of individuals; according to the latter a disease consists in a determinate deviation of some part of the economy from its healthy structure or function, in some determinate proximate cause.

Much has been said and written lately, in some medical schools, of the great superiority of the plan of investigating diseases with a view to the pathological conditions on which they depend, over that which principally occupies itself with the examination of the symptoms which they exhibit. It does not appear to us, however, that there is either necessity for, or justice in, depreciating the one branch of inquiry in order to exalt the other. It must be the object of an enlightened cultivator of medical science to obtain every information in his power respecting diseases considered both in reference to the symptoms which they exhibit, and to the pathological states, morbid conditions or proximate causes on which they depend. However great the difficulty may be of accurately marking the symptoms of diseases, that of referring them to their proximate causes is infinitely greater, and it is not therefore to be wondered at, that these two branches of inquiry are not equally advanced. But because we have become more sensible of the importance of being acquainted with those elementary changes in structure and function on which deviations from the healthy condition of the economy depend, we are by no means entitled to speak slightingly of the labours of those, who by their diligent and accurate examination of diseases, in reference to the more or less regular combinations and successions of symptoms, have demonstrated the necessity of, and prepared the way for, this other branch of medical inquiry.

Progress of investigation in pathology. In pathology, or the investigation of diseases, as in the other departments of inductive philosophy, the order in which those proceed who attempt to extend the limits of human knowledge, and that which is followed by those who are endeavouring to communicate to the uninformed the acquisitions that have already been made in this branch of medical science, are essentially different. In their original investigations, pathologists seek to advance from the knowledge of individual facts respecting morbid structure and morbid function, to the establishment of general principles; whilst in their instructions they commence with the exposition of general principles, and descend from these to the enumeration of the particular facts which these principles connect, or which, to use the ordinary language, they serve to explain.

If we carry ourselves back in imagination to the earliest ages of medicine, we shall be sensible that it was only in the examination of individual cases of disease that the pathological studies of the practitioners of those days could consist. But by comparing the cases that fell within their observation, they would be led to notice various circumstances in which they resembled or differed from one another. If we could suppose them to have attempted to record the histories of these cases, they must have found that the work involved them in a great deal of repetition, from the similarity of the symptoms which presented themselves in a number of different individuals; a similarity that must have appeared the greater to these early observers, from its being only the outstanding or prominent features of the cases to which their attention would be given. On the observation of such a similarity amongst individual cases, must have been founded the recognition of particular diseases, such as ague, rheumatism, apoplexy, pleurisy, and dysentery, a specific name being given to every combination or series of morbid phenomena that was observed to occur with considerable regularity in a number of different persons, just on the same principle as a specific name is given to every other

Disease. group of objects which exhibit a general correspondence in their qualities or characters. It must have been in this way that the transition was made from the consideration of individual cases of disease to that of particular diseases, and that the pathologist of those early times, instead of confining himself to drawing up an account of each single case in all its minutest details, would be led to generalize the results of many similar cases; first, perhaps, in relation to particular circumstances of their history, and afterwards in relation to their whole course or progress, so as ultimately to produce a delineation exhibiting those more prominent and more important characters in which the whole group of cases agreed, without its being overloaded with the trivial and accidental circumstances peculiar to each.

Nosography, and diagnosis. To designate that branch of pathology which is occupied with the detailed description of particular diseases, (the *Prima Medicina sive Historia Morborum* of Baglivi,) no more suitable term perhaps has been invented than that of Nosography, employed by M. Pinel. The marking of those phenomena and circumstances by which particular diseases are especially characterised, has long been considered as a peculiar branch of medical inquiry under the name of Diagnosis.

Semeiology. But the processes of comparison and contrast which were necessary for establishing and describing particular diseases, must have called the attention of medical men to a number of points in which different diseases correspond with or differ from one another; and thus have opened up to them views of disease extending not only beyond the consideration of individual cases but even beyond that of particular diseases. Thus, when it was found that the same individual symptom, such as quickness of pulse, headache, cough, vomiting, or purging, may occur in several diseases, which in other respects differ very essentially from one another, this observation would suggest an inquiry as to the different conditions of the economy in which each particular symptom of disease may occur; and in this manner would be established a general doctrine in medical science, having for its object to consider individual symptoms of disease in all their various relations; a department of inquiry to which the names of Semeiology or Symptomatology have been assigned.

Prognosis. To the friends of the sick it is naturally an object of great anxiety, at as early a stage of their malady as possible, to be able to anticipate its ultimate result as well as general progress, and the more striking phenomena which it will exhibit in its course: and the skill of the medical practitioner is in a great measure estimated by the bystanders, according to the accuracy of his predictions on these subjects, or, as it has been termed, of his prognostics. To be able particularly in the early periods of diseases, from the contemplation of the present to anticipate the future, when to the unpractised eye every thing seems involved in general obscurity and doubt, has accordingly been at all times a very favourite object with medical men; and those who are acquainted with the writings of the father of medicine must know how large a share of them is occupied in laying down rules to guide the practitioner in the formation of his prognostics, principally founded on the results of his own extended observation. No portions of his writings, indeed, more fully justify, than those which relate to Prognosis, the eloquent observation of M. Prunelle, that "the works of Hippocrates present the most striking application of that philosophic method, which, creating axioms out of observations, and transforming the results of particular facts into general rules, furnishes the human mind with the most active instrument for perfecting the sciences." The anticipations of the medical practitioner respecting the future progress of individual cases of disease must, it may be remarked, be founded on the occurrence of particular single symptoms, or of particular combinations of symptoms, and must be influenced in many cases by the constitution of the individual affected, or by the external circumstances to which he has been or is subjected, such as the prevailing atmospheric constitution, or the character of the reigning epidemic. Disease.

Nosology. It must soon have been found that it is not individual symptoms only that are liable to occur in several different diseases; but that certain determinate combinations of symptoms may be common to diseases which nevertheless are marked as different from one another by the other symptoms with which, in each of them, these common phenomena are combined. Such, for example, are the particular groups of symptoms by which fevers, inflammations, hæmorrhagies, dropsies, &c., are characterised, each class comprehending a number of diseases, which all correspond to a certain extent in the symptoms by which they are accompanied, and at the same time all differ widely from one another in other respects, according to the particular organ which may be the more immediate seat of disease. The observation of such general analogies or resemblances in the symptoms of different diseases, and the employment of general terms to designate them, would suggest to medical men the idea of classing diseases in more or less numerous families or groups, such as those which we have just named. Other grounds of classification would be found in the resemblances or differences of particular diseases in regard to their general course and ultimate result, suggesting such distinctions of diseases as those into acute and chronic, continued and intermittent, mild and malignant, &c. It has been, however, in comparatively recent times, that the classification of diseases, combined with their nomenclature and definitions, has been erected into a separate department of medical science under the title of Nosology.

Proximate causes. In watching the various preternatural phenomena which the several functions of the economy are liable to exhibit in the state of disease, medical men are naturally led to consider what the changes in the internal conditions of the corresponding organs of the body can be, which give rise to those deviations from the ordinary exercise of the functions, that constitute the symptoms of diseases. The attempt to ascertain the internal conditions of the economy on which the external phenomena or symptoms of diseases depend, or, in other words, to ascertain the Proximate Causes of diseases, though it has unquestionably involved medicine in much unprofitable, or rather injurious speculation, is as legitimate and necessary a subject of investigation as any other department of the science. It has been in the attempts of medical men to arrive at extensive generalizations of the proximate causes of diseases, whilst their observations were still too imperfect and too inaccurate to serve as a foundation for such attempts, that the various systems of medicine have had their origin, which have at different times been proposed. A very slight analysis of these various systems, would, we believe, be sufficient to shew that however great may be the diversity of opinion which they seem to embrace, they are all founded upon a few leading assumptions which may perhaps be expressed in the following propositions:

General theories of disease. 1. That diseases depend upon morbid changes in the chemical composition of the different parts of the body, and particularly of its fluids. This principle forms a prominent feature in the doctrine of the four humours entertained by Hippocrates; in that of salt, sulphur, and mercury, adopted by Paracelsus; in that of ferments, suggested by Van Helmont; in that of acid and alkali, maintained by Sylvius; and of those other doctrines founded upon the more accurate knowledge of chemical elements that has been obtained in modern times, which have been proposed by Baumes and others.

2. That the physical conditions of the solids and fluids of the body, furnish the proximate causes of diseases. This has served as the principal groundwork for the doctrines of the medico- or iatro-mathematicians, Borelli, Bellini, Bag-

Disease. livi, &c.; but it may be traced back to a much earlier origin in the Methodic school of medicine, founded on the corpuscular or atomic system of philosophy; in the hypothesis of Asclepiades respecting the dependence of disease on the relative proportions of the pores and of the circulating fluids; and in that of Themison, who regarded all diseases as depending on a lax or a strict condition of the solids of the body.

3. That the primary agents in the production of morbid phenomena are those peculiar vital powers different from the physical and chemical properties of inorganic matter, with which the living animal economy is endowed; sensibility, irritability, and an influence supposed to be exercised by the nervous system over the organs by which the natural and vital functions are performed, which some have designated animal power, cerebral action, or energy of the brain, and others innervation or innervatory influence. Of this doctrine Hoffmann seems first to have opened up the leading principles. The researches of Haller and of Whytt, and the pathological speculations of Cullen and Bordeu, gave it a still farther extension; and in the hands of Brown it received, what it has in some medical schools retained, the form of an exclusive system.

4. That in addition to its known vital, and to its physical and chemical properties, there is implanted in the animal economy one great, superintending, independent power or principle which regulates all its actions both in the state of health and of disease. Such has been supposed to be the principle denominated nature or innate heat by Hippocrates; pneuma, or spirit, by Athenæus and the other members of the Pneumatic school; archeus, by Paracelsus and Van Helmont; and vital principle by Mr. Hunter in this country, by M. Barthez in the school of Montpellier, and by their respective followers.

It is not easy to say whether we ought to include under the last of these assumptions the animistic doctrine of Stahl, or to consider it as resting upon a separate and fifth assumption, viz. that the phenomena of the human economy, in the state both of health and of disease, are under the immediate government or control of the soul. When the term soul is employed as synonymous with the rational mind, as it seems to be by Stahl, the animistic doctrine must obviously be considered as distinct from all the other assumptions; but when the soul is spoken of as governing the functions of the body without the exercise of reason, the doctrine seems to ally itself with the principles mentioned under our fourth proposition.

Respecting the different theories of disease, it may be remarked, that each of them has varied in its outline and details at different periods, according to the general state of knowledge and the prevailing system of philosophy. It must be kept in recollection, also, that whilst in some systems one of the assumptions above enumerated serves as the sole basis or foundation of the doctrine, in other systems two or more of them are combined. Thus Hippocrates united in his system the doctrine of nature or innate heat with that of the four humours; Athenæus that of the four elements with the pneuma; Paracelsus that of the body being composed of salt, sulphur, and mercury, with the doctrine of the archeus; and Hoffmann the influence of the nervous system, with the doctrines of the iatromathematicians. "In reviewing," says Buffalini, "the different theories or systems of pathology that have successively prevailed during the long period that has elapsed from the age of Hippocrates to our own time, we cannot fail to be struck by two circumstances; the *first*, that almost the whole of these systems are founded not on observations relative to the animal economy, but for the most part on the prevailing doctrines of the schools of philosophy; the *second*, that all of them (perhaps without exception) have had their origin in a very small number of fundamental errors, which, from being differently clothed and adorned, give the appearance of great variety, where in fact there exists a great similarity, of opinions." Disease.

The ancient systems of medicine are now very generally regarded as being so many attempts, founded on very partial and often erroneous observation, to reduce the whole physiological and pathological phenomena of the economy to a few primary principles; a simplification which it is hopeless to expect to attain, at least till these phenomena are much better understood separately, and in their relations to one another, than can for a long period be expected. The more correct views that at present prevail respecting the peculiar properties of animal bodies, for which medical science is so much indebted to the labours of Haller; and the extended knowledge that has been obtained respecting the morbid changes liable to occur in the physical and chemical conditions of the solids and fluids of the body, have certainly tended much to introduce a greater degree of precision than was formerly judged necessary, into the notions which pathologists entertain relative to the proximate causes of diseases.

It is in an order of advancement such as we have endeavoured now to trace, as having necessarily been followed by the early cultivators of medicine in regard to the deviations of the economy from its healthy condition; that is, in advancing from the consideration of individual cases to that of particular diseases, and from these, again, to general views of disease, that those must proceed who seek to improve the science of pathology. But where the object is to convey to others the results of the acquisitions that have already been made in the knowledge of disease, the order that may be most advantageously pursued is directly the reverse of this. Our view of diseases should commence with explaining the general principles that have been established respecting morbid structure and morbid function, considering each change of structure or function as constituting in itself a specific object of investigation, in all its possible effects, and in all its possible modes of production. It is in this way that we should be prepared to enter on the consideration of those combinations of symptoms which constitute or rather which mark particular diseases; to view each disease in respect of the course which it runs, the symptoms which it exhibits in its successive stages, and by which it is characterised and distinguished from other particular diseases; the nature and seat of the morbid actions, and of the morbid alterations of structure from which it may arise, or which it is liable to produce; and the circumstances which indicate a favourable or unfavourable termination to it. With a knowledge of particular diseases, in these various relations, such as is to be acquired from books and from lectures, the student is prepared for being conducted by an experienced practitioner to the bedsides of the sick, and for having his attention directed to the phenomena of diseases as they present themselves in individual cases.

From this sketch, slight and imperfect as it has been, it is apparent that the consideration of the economy in its diseased states, or the department of pathology, presents itself to the cultivator of medical science under three general aspects: 1st, that of the general doctrines of morbid structure and function, or general pathology, a branch of medical science which, though too long kept in the back-ground in the medical schools of this country, in consequence of its having been associated, in the courses of instruction, with other very interesting and very extensive departments, is now beginning to vindicate its due share of attention; 2d, that of the history of particular diseases, nosography or special pathology; and, 3d, that of the examination of individual cases of disease, or clinical medicine. And whilst the business of the teacher commences where that of the original investigator terminates, in the consideration of general principles, it terminates where that of the original investigator commences, in the investigation of individual cases of disease. General divisions of pathology.

Ætiology. III. Besides an acquaintance with the human economy in its healthy and in its morbid conditions, we have said that the science of Medicine includes an acquaintance with Morbific causes and Remedial powers. The advancement of medical men in the knowledge of these two classes of agents, and their modes of considering them respectively, must have kept pace with their progress in the investigation of diseases.

Morbific causes. 1. Whilst the attention of the pathologist was confined to the examination of individual cases of disease, he would naturally be led to inquire into the morbific agents, single or combined, by the operation of which each individual case had been produced; and in like manner, in combining groups of similar cases under general denominations, so as to establish particular diseases, it would be noticed that each disease, beside corresponding in the phenomena which it presented to the observer, in the different individuals in whom it occurred, also corresponded very generally in respect of the cause or causes by which it had been excited. On further investigation, however, it would be found that different diseases may arise from the same cause, as that rheumatism and pleurisy may both be produced by the operation of cold; and that different causes may produce the same disease, as that intense heat and intense cold may equally excite inflammation and gangrene. Medical men would then naturally be prompted to inquire what are the circumstances of correspondence and difference among the different causes of disease upon which it depends, that in their operation on the economy, similarity or identity of effect may arise from diversity of cause, or diversity of effect from similarity or identity of cause; and a foundation would thus be laid for the consideration of morbific causes, or what is usually termed Ætiology, as a general doctrine in medical science.

It is the province of ætiology, therefore, to ascertain what are the various powers that are capable of exercising an injurious influence on the human economy; to arrange these powers according to the most commodious classifications; to inquire into the channels through which those of them that are exterior to the body find their way into it; to ascertain upon what part of the constitution each of them primarily acts; and what is the nature of the change or changes in the economy, organic or functional, to which each of them gives rise. The study of ætiology presents, indeed, a very wide field of investigation; for there is scarcely any agency in nature, material or mental (not excluding even those agents by which, under ordinary circumstances, the economy is maintained in a state of health, and those by which it is restored from a morbid to a healthy condition) that may not, under some circumstances or other, contribute directly or indirectly, immediately or more remotely, to induce the state of disease.

Predisposition to disease. Independently of the material morbific agencies, physical, chemical, and vital, by which the human body is surrounded, and of the injurious influence which mental emotions may exercise upon it, there are frequently inherent in its own constitution, conditions that exert very important influences in the production of diseases and in the determination of their characters; conditions which, as marking deviations from the healthy standard, might be in some degree regarded as proximate causes of disease, but which, from the deviations being too slight to manifest themselves by any symptoms sufficiently characteristic of their existence, pathologists are wont to consider not as actual states of disease, but only as *predispositions* to disease. It is to this head of predispositions that medical men refer the diversities of temperament, constitution, or diathesis which different individuals exhibit, and which appear in some instances to be born with them, and in others to be acquired in the progress of life.

Remote causes. As the pathologist regards the symptoms of diseases as the consequences or effects of deranged conditions of certain portions of the economy, so he regards those morbid conditions in their turn, as the consequences or the effects of the operation of morbific agencies; and as the term *proximate causes* is employed to designate the morbid conditions, structural or functional, which give rise to the symptoms of diseases, so the term *remote causes* is used to denote the agencies by which these morbid conditions or proximate causes are themselves produced. The agency of the remote in exciting the proximate causes of diseases, must ever be a leading object of investigation to the scientific physician; since it is obvious that his power of arriving, in particular instances, at a knowledge of the proximate cause of a disease, must be materially aided, if, in addition to the judgment which he forms as to its nature from a consideration of the existing symptoms, he can also form a judgment upon this subject from a consideration of the causes by which it has been induced. Thus, for example, an acquaintance with the various effects which mental emotions are liable to induce in the economy, frequently enables the medical practitioner, (as in the case of affections of the heart), to correct the judgments which, from a consideration of the symptoms alone, he would be disposed to form of the nature of the diseases with which his patients are afflicted.

The extent of the difficulties that are experienced in endeavouring to trace the influence of morbific agents in inducing disease, may be inferred from the many points which, as is well known even to unprofessional persons, are still matters of doubt and controversy, relative to the origin or production, and to the diffusion or propagation of those two morbific powers which have been denominated *specific*, viz. terrestrial miasm or malaria, and human contagion. That an acquaintance with the laws which regulate the operation of the other agencies or influences that induce disease (the *general* or *common* morbific causes) must be still more difficult of attainment, may reasonably be presumed; since, whilst each of the specific agents uniformly produces, whenever its operates, one determinate or specific form of disease, each of the common exciting causes, on the contrary, may produce various forms of discase, according to the degrees and combinations in which it is applied to the human economy, and according to the particular circumstances in which the economy may at the time exist.

Hygiène. The term Hygiène has long been used as synonymous with the art of preserving health, to designate the consideration of the means which ought to be employed for maintaining the economy in a sound condition. It was justly remarked by Dr. Cullen, however, that there is truly no other means of preserving health, but what consists in the prevention of diseases; and that this again can be effected only by the avoidance of their exciting, or by the correction of their predisposing causes. Ætiology, as treating of the sources of the exciting causes of diseases, and of their modes of action, is the necessary foundation of that part of hygiène which relates to their avoidance; whilst the correction of predispositions is really and truly, as Dr. Cullen observed, the removal of diseases; and the means of accomplishing it are no other than the remedies we employ in curing diseases, so that they may with propriety be comprehended under the title of therapeutics.

Medical statistics. It is on the consideration of morbific agencies, as acting upon large masses of men, that Medical Statistics are founded; this branch of investigation having for its principal object to ascertain the influence which peculiarities of climate, of diet, of occupation, &c., exercise on the populousness of different regions; on the liability of mankind to disease; on the characters of the maladies to which they are subject; and on the age to which they attain. To a country like this, holding such extensive colonial possessions in very different quarters of the globe, and having its own population engaged in so many kinds of employment, civil and military, agricultural, manufacturing, commercial, and maritime, medical-statistical inquiries are both interesting and important.

Remedies. Remedial powers.

2. In considering the action of Remedial powers, the attention of medical men, it may be supposed, would first be directed to the effects produced by particular remedies in individual cases of disease. When they had advanced to the recognition of particular diseases, they would be encouraged to make use of those remedies which had proved beneficial in one case, in the treatment of other cases of what they regarded as the same disease; and lastly, when they had formed some notions of the internal morbid conditions, or proximate causes, on which different diseases depend, they would extend the employment of those remedies which seemed to have assisted in removing a particular proximate cause in one disease, to all diseases in which there seemed reason to suspect the existence of similar pathological conditions.

The measures which are in use for the prevention, cure, or alleviation of diseases, may be referred to three heads: *First*, those which relate to the management or regulation of those circumstances that are included under the head of regimen, such as the diet of the sick, the temperature and other qualities of the atmosphere in which they live, their clothing, and their exercise, bodily and mental,—comprehending, obviously, what used, in the language of the schools, to be called the non-naturals; *second*, the various operations requiring manual skill or dexterity, which it is necessary to perform for the relief either of internal or external diseases, such as the application of bandages, the operation of bloodletting, &c.; and, *third*, those substances which by experience have been found, when introduced into the system, to exert some influence on the economy that tends to restore it from some one of its diseased states to a healthy condition; as, for example, those substances which remove spasm and allay pain, (anti-spasmodic and narcotic medicines, as they are termed), and those which increase the alvine or the urinary evacuations, either when the action of the organs by which these evacuations are effected is deficient, and it is desired to restore them to their natural vigour, or when it is wished to increase their activity beyond its ordinary degree, laxative or purgative, and diuretic medicines.

An acquaintance with the substances which exercise beneficial influences on the diseased economy is obviously of essential necessity to the practitioner of physic. Of these substances some are derived from the vegetable, others from the mineral, and a few from the animal kingdom; and hence arises, in part at least, the importance to the medical practitioner of being acquainted with the sciences which treat of these several departments of natural history. But whilst some medicinal substances are employed as they exist in nature, or after undergoing some slight and unimportant manipulation, others can be obtained only by long and elaborate processes, many of them involving a knowledge of the principles of chemical science; and here again we see, in part at least, the cause why chemistry, since its earliest dawnings, has been regarded as essentially allied to medical science. "Every substance," as was observed by the late Dr. A. Duncan, jun., "employed in the cure of diseases, whether in its natural state, or after having undergone various preparations, belongs to the materia medica, in the extended acceptation of the words. But in most pharmacopœias the materia medica is confined to simples, and to those preparations which are seldom prepared by the apothecary himself, but commonly purchased by him, as articles of commerce, from druggists and chemical manufacturers." It is the province of Pharmacy to consider the preparation which medicinal substances require in order to fit them for the purposes of the medical practitioner; whether these changes shall be of a mechanical or chemical nature; whilst the consideration of the effects which medicines and other remedies are capable of producing on the different systems and organs of the economy, constitutes that department of medical science usually denominated general Therapeutics. All these various kinds of knowledge relative to medicines, their natural history, their pharmaceutical preparation, and their therapeutical powers, it has been by some proposed to include under the general title of Pharmacology. Remedies.

Sources of improvement in the knowledge of remedies

The improvements that have been made, or that remain to be made, in the department of materia medica, may consist either in making additions to, or subtractions from, the number of substances employed for medical purposes. Additions may be made to the number of medicines either from the discovery in substances already known, of powers or virtues which they were not known to possess, or from the discovery of entirely new substances possessing therapeutical powers. The baneful influence of spurred rye in producing gangrene has been long known, but it is only of late that attention has been particularly called to the power which that substance is by some alleged to possess of exciting the contraction of the muscular fibres of the uterus. The noxious influence of the different acetates of lead, when internally administered, has likewise been long known, and particularly their effect in exciting colicky pains, but it is of late only that their influence in suppressing excessive intestinal evacuations, and in restraining hæmorrhages, has particularly attracted the attention of medical men. Iodine, on the other hand, may be mentioned as an instance of a substance which within a short time after its discovery, acquired a high character in the estimation of many practitioners, for its therapeutical virtues. The history of the croton oil, the powerful action of which upon the intestinal canal is now familiar to every one, affords a remarkable example of a medicine the knowledge of the powers of which has been very slowly diffused among medical practitioners. It would appear that the seeds of the croton tiglium have been in use among the natives of the East from time immemorial, and that they were formerly known in Europe as a drastic purgative, under the name of grana molucca or grana tiglii. They had fallen, however, into oblivion, when the attention of the profession was again called to them by the observations in Sir Whitelaw Ainslie's *Materia Medica of Hindostan*, that gentleman having been induced to point out this medicine to the particular notice of the medical men of India, from finding that it was highly prized by the Hindoo doctors, and extolled in various *sastrums* or professional tracts. It appears, moreover, that the oil, in which the purgative virtue resides, was first prepared and used in medicine by the Dutch surgeons in India, about a century ago, a single drop taken in Canary wine being employed as a common purgative. It is only, however, within these few years that the use of the croton oil has been introduced into Europe.

The difficulty that is experienced in arriving at a sound judgment with regard to the medicinal powers of the remedies which every now and then are obtruded on public notice, with lofty and but too often exaggerated panegyrics, renders it very necessary to rid the pharmacopœia from time to time of inert and useless substances. The expulsion from our pharmacopœias of a great many substances of this description within the last century, and the much greater degree of reserve with which new substances are admitted into them, than was formerly practised, afford a gratifying proof of the steady advancement of correct discrimination in this department of medical science.

The progress which has recently been made in chemical knowledge has contributed very materially to improve the department of pharmacy. This improvement is particularly conspicuous in the preparation of vegetable medicinal substances. The employment of steam instead of fire in the preparation of vegetable extracts, presents an elegant though simple illustration of a pharmaceutical process improved upon chemical principles. The separation from many vegetable substances of the principles on which their medicinal virtues depend, so as to allow of these being administered free from a quantity of useless and possibly hurtful matter, (as the separation, for example, of quinine from bark), affords

Remedies. an illustration of a still more elaborate and not less important application of chemistry to pharmaceutical science.

If it be reasonable to expect that medical men are to be aided in the treatment of diseases by an improved knowledge of their nature, therapeutics cannot fail to derive benefit from every advancement that is made in pathological science, and particularly in the knowledge of the proximate causes of diseases. But the action of remedies in restoring health is so dependent upon, and so mixed up with, the natural or spontaneous operations of the economy, as to render it at all times a matter of the utmost difficulty, for the most careful and candid observer, to determine or even conjecture what part of the result is attributable to the one, and what to the other of these joint influences. It must be confessed, indeed, that we are still far from knowing what nature accomplishes in different diseases by her own unassisted efforts towards the restoration of the diseased body to a sound or healthy condition; what she accomplishes when judiciously assisted by medical art; and what she does not effect either singly or with all the aid that medicine is able to render her. These are the great problems in therapeutics, for the solution of which it must be the main object of scientific practitioners to furnish the necessary materials. There can be no doubt that morbid anatomy, by the light which it has thrown upon the proximate causes of diseases, has contributed very much to correct and extend the views of medical men as to what is curable and what is incurable in disease, as well as to guide them in forming their therapeutical indications. Thus, it may be remarked, that to the success of medical practice, nothing is more important than the power of discriminating when a stimulant or repleting, and when an antiphlogistic or depleting mode of treatment ought to be pursued. The knowledge that has been obtained, by means of dissections, of the circumstances under which inflammatory affections are liable to develope themselves in the different organs and textures of the body, in the progress of various diseases in which their occurrence is apt to be overlooked, has been of great use in assisting medical men to discriminate the cases in which these two plans of treatment are respectively to be preferred.

Specifics. In reference to the progress and present state of therapeutical science, it deserves to be noticed, that in proportion as medical men have become better acquainted with the operations of the economy in its healthy and morbid conditions, the number of medicinal agents reputed to be possessed of specific therapeutical powers, that is, to be capable of exercising a beneficial influence in curing particular diseases, without any external manifestation of their immediate mode of operation, on which their beneficial influence may be supposed to depend, has gradually diminished. This may be attributed, perhaps, in part to medical men having been able to ascertain the particular actions which these supposed specific medicines exert upon the economy; and partly to their being less credulous in admitting the efficacy of remedies, of whose mode of operation they are unable to form any conception.

Accessory sciences. Such is a slight view of the three departments into which we have said that medical science admits of being divided; —that which considers the human economy in the state of health; that which considers the same economy as affected with disease, and that which investigates the powers or agents by which health may be banished and disease produced, or on the other hand, disease dispelled and health restored. But besides those branches of knowledge that are to be regarded as more strictly medical, there are others, an acquaintance with the principles of which is most important or even essential to the cultivator of scientific Medicine. It is to these that the well-known observation of Celsus is applicable, "Quanquam multa sint ad ipsam artem proprie non pertinentia, tamen eam adjuvant, excitando artificis ingenium: itaque ista quoque naturæ rerum contemplatio, quamvis non faciat medicum, aptiorem tamen medicinæ reddit." Amongst the sciences auxiliary or accessory to medicine may be justly reckoned natural or mechanical philosophy, chemistry, and natural history. Acessory sciences.

Mechanical philosophy. A knowledge of mechanical philosophy is indispensible to a right understanding of the actions of several of the organs of the body in the state of health, and consequently of several of the deviations from the healthy state to which these organs are liable in disease; and this knowledge is necessary also to the right comprehension of the action of several external agents upon the body, both in the state of health and of disease.

Though the higher phenomena of the human body arise from its being endowed like the bodies of other animals with peculiar vital properties, and from its being associated with a rational mind, yet it must still be regarded as a piece of mechanism of the nicest and most elaborate construction; and it is impossible to arrive at correct or enlarged notions with regard to its structure without possessing an adequate knowledge of the principles of mechanics. Hence it is, indeed, that the language of anatomy is replete with terms derived from mechanical science. The study of animal mechanics, or what may be termed structural physiology, that is, the consideration of the mechanical contrivances discoverable in the construction of the different parts of the body, a branch which furnishes so ample a field of illustration to the student of natural theology, essentially requires to be combined with the study of anatomy; since without it the latter would be only a dull and uninteresting record of names, forms and dimensions. Thus, for example, to give an interest to the study of that extensive portion of the animal frame which is subservient to voluntary motion, it is essential that each muscle, bone and joint should be considered in its mechanical relations: and nothing certainly can be more calculated to excite admiration than, in contemplating the arrangements of these parts in reference to the properties of the lever, as constituting respectively the moving power, the resistance and the fulcrum, to become sensible of the advantages that are obtained in respect of elegance of form and rapidity of movement, by the sacrifice of a portion of that force with which the muscular fibres have been so largely endowed.

It would be easy to adduce many illustrations to shew how essential a knowledge of mechanical principles is to the comprehension of the vital and natural functions of the animal economy. The inquiry as to what the powers are by which the blood is moved through the body, is one which cannot be properly prosecuted without an acquaintance with the laws of hydraulics. It is to the too frequent ignorance on the part of physiologists, of the principles of mechanical science, that must be attributed much of the doubt which still prevails on many points relative to the function of circulation, and particularly as to whether the motion of the blood depends wholly upon the propelling powers of the organs within which it is immediately contained, or with which these are themselves surrounded; or whether it be not partly attributable to the pressure of the atmospheric air over the whole surface of the body, acting in co-operation with the production of a vacuum at the central organ of circulation. From finding themselves unable to refer all the various motions that are observed to occur in the solid and fluid parts of animal bodies, to the known properties of inorganic matter or of organic structure, some physiologists have been led to imagine that there exists in these bodies a secret or unknown principle capable of giving rise to various physical motions, as well as of producing other phenomena, in the economy; and to this principle they have given the name of the *vital power*. It seems reasonable, however, to hope that in proportion as we shall obtain a more precise knowledge of the motions that actually occur in animal bodies, and of the principles or

Accessory sciences.

sources of motion that are in operation throughout organised and unorganised nature, the occasion will cease for employing this ambiguous and uninstructive term. It is proper indeed to keep in mind that within no very great length of time, several different kinds of motions occurring in inorganic bodies have been brought to light, which probably exercise considerable influence on the functions of organised beings. To these may be referred the motions performed by extremely minute particles of solid matter, whether obtained from organic or inorganic substances, when suspended in pure water or in some other aqueous fluids; and which from their irregularity and seeming independence, resemble in a remarkable degree the less rapid motions of some of the simplest animalcules of infusions. We have another example of a recently discovered principle of motion in endosmosis and exosmosis, or that power or property in virtue of which there takes place a reciprocal transmission through all organic membranes and some inorganic laminæ, of fluids which are in contact with their opposite surfaces, and which differ from one another in certain physical conditions. An analogous principle of motion has also been found to operate in the case of gases and to regulate their diffusion. It would be out of place to inquire here what particular phenomena in the animal economy have received, or may receive, elucidation from these or other sources of physical motion of which we have recently arrived at the knowledge. But it is obvious, that besides these, there may be yet undiscovered sources of physical motion, operating in the production of those phenomena in the economy of living beings, which physiologists, from not being able to refer them to any of the known sources of motion, have been wont to regard as the effects of a peculiar vital principle.

There are many problems in pathology also, for the solution of which it is absolutely necessary to appeal to the principles of mechanical science. Thus it has been of late only that pathologists have sufficiently turned their attention to the physical considerations which it is necessary to keep in view in any explanation that may be attempted of the conditions of the encephalon, (that is, of the brain and the solids and fluids connected with it), upon which the production of coma or insensibility depends, viz. *first*, the unyielding nature of the cranium, or bony case of the encephalon; *second*, the exemption of the encephalon, so long as its bony case remains entire, from the pressure of the atmosphere, except in one direction, the aperture at the base of the skull, through which the spinal marrow passes; and *third*, the impossibility of the entire encephalon or any of its parts, undergoing a sensible degree of compression from any force to which they can be subjected during the continuance of life. Again, in surgical pathology, we have an illustration of the benefits to be derived from a knowledge of mechanical principles, in the light which they have thrown upon the variations in the effects produced by penetrating wounds of the chest, according to the proportion between the size of the wound and of the aperture of the glottis; and according as the substance of the lungs has or has not itself been injured, so as to allow of air passing from the respiratory cells into the cavity of the pleura. Those who require more immediate illustrations of the applicability of mechanical science, to practical purposes in the removal of disease, may find many such in the contrivance and application of surgical instruments and apparatus. The advantages to be derived in many diseases from the observance of the horizontal posture, and from bandaging, simple as these means appear, would probably be more duly appreciated than they are, were medical men more in the habit of considering the physical influences to which the body is subjected.

Chemistry.

Of the applicability of chemistry to the several branches of medical science, notice has been taken in speaking of each of these branches successively. We need not repeat how important an acquaintance with chemistry is to the practitioner of pharmacy. The anatomist derives assistance from chemistry in the prosecution of his researches. The physiologist finds that many of the phenomena occurring in the animal economy depend on processes of combination and decomposition; and are as strictly of a chemical nature as any which are conducted in the laboratory of the chemist on unorganized substances. The pathologist has learned that from various circumstances these chemical processes are liable to be deranged, so that the products are different from what they should be; and the therapeutist has hence been led to enquire what are the appropriate remedies by the administration of which the natural composition of the products may be restored. From the light which has been already derived from this branch of science, since it was first applied to the investigation of the phenomena of the animal economy in health and disease, we are warranted in anticipating that it will still powerfully contribute to elucidate many points in medicine which are at present involved in obscurity. "The imperfection of pathological chemistry," says M. Prunelle, "obliges us to refer to the *vital* forces, a host of diseases which necessarily depend on lesions of mixture. A great number of physiological and pathological phenomena which we consider at present as dependent upon the vital forces, will pass under the domain of the chemical and the organic forces, in proportion as the laws of these forces shall be better known and more generalised."

Accessory sciences.

Natural history.

With regard to the applicability of a knowledge of natural history to purposes of medical science, it may be remarked, that whether we consider the human economy in the state of health or of disease, or turn our attention to the operation which morbific or therapeutic agents exert upon it; in each department important aid may be derived from an acquaintance with the three kingdoms of nature.

Animal kingdom.

How much assistance we receive in attaining an accurate knowledge of the structure and functions of the human body, from tracing through the successive series of animals, the instruments that are subservient to their several functions, and the manner in which these functions are exercised, there has already been occasion to remark. It seems reasonable to expect, that as the study of the lower animals has contributed to improve our knowledge of the anatomy and physiology of man, so, in like manner, much benefit should accrue to pathology from similar comparative investigations. Morbid anatomy, for example, ought certainly to be prosecuted to much advantage in the inferior animals, not only from the parts being, in some cases at least, upon a larger scale, but from our having an opportunity, by putting the animals to death, to trace the effects which the action of different morbific causes produces upon the structure of their different textures and organs; as well as to examine the changes which diseases induce in the successive stages of their progress. The experiments and observations that have been made with regard to the development and progress of cysts and tubercles in the lungs and other organs of some of the lower animals, besides suggesting some interesting views respecting the series of changes that occur in morbid structures, have given rise to important considerations respecting the circumstances under which these morbid changes of structure are most liable to take place. The liability of animals kept in confinement to undergo diseases from which they are exempt, or to which they are less subject in their natural condition, suggests another hint that may prove serviceable in the study of morbific causes. A very direct source of interest in veterinary medicine arises to the physician, from the fact that some of the diseases depending on specific contagions, to which the lower animals are liable, are capable of being communicated to the human subject. It is to the observation of a fact of this kind that we are indebted for that most invaluable discovery, the protection against small-pox afforded by having

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passed through a disease which, whatever may be its primary source, is best known as occurring upon the udder of the cow. The other diseases which are liable to be propagated from brute animals to the human species, such as hydrophobia, glanders, *pustule maligne*, &c., we know only by the injurious effects which they produce.

From the correspondence of many of the diseases of the lower animals with those of man, it seems obvious that animals may be made the subjects of therapeutical as well as of physiological and of pathological experiments. The use of the cautery, for example, particularly in diseases of the joints, has probably been advanced in surgical practice from the experience which veterinary surgeons have obtained of the beneficial effects of *firing* upon the horse.

It may be remarked too, that whilst a large portion of the animal kingdom is rendered subservient to mankind in the way of food, and a few animals supply remedial agents, there is a considerable number which produce, in various ways, noxious or poisonous effects upon the economy. Certain animals secrete, when in the state of health, noxious fluids which serve them as means of attack and of defence, on account of which power they are designated under the common name of venomous animals. These animals, of which the mammalia and birds do not present any species, are found principally among the serpents, insects, and zoophytes. It has been alleged that some fishes also are capable of communicating a venomous character to the wounds which they inflict with their prickles. But fishes and some species of mollusca are better known for their poisonous qualities when employed as articles of food. Of poisonous fishes, again, there are some which are essentially poisonous, that is to say, they are so at all times, although they are not distinguished by any anatomical character from those which are most salubrious; whilst other fishes which are in general more or less healthful and agreeable as articles of food, become hurtful only accidentally; whether their noxious character then depends, as some have supposed, upon the season, or, as others have imagined, upon their having made use of a particular kind of nourishment; or, as others again have conjectured, is attributable to a particular morbid state, and the consequent formation of a poison *sui generis*, that is diffused over the whole substance of the animal. It is sufficiently obvious that for the acquisition and extension of this species of knowledge, and for the power of turning it to account in the different circumstances in which they may be placed, medical men must be dependent on an acquaintance with zoology.

Vegetable Kingdom.

The most important benefit, certainly, which medicine derives from the knowledge of the vegetable kingdom is in relation to the purposes of the materia medica, and to the investigation of poisons. Botany, however, is not without its use in the elucidation of the functions of the animal economy. In plants we have an opportunity of witnessing the performance of two classes of functions, those essential to the preservation of the individual, and those necessary for the continuance of the species, under the most simple conditions in which they can be executed. And, independently of any resemblances that might be traced in the functions of circulation and secretion as performed by plants and by animals, those which have been ascertained to exist between the chemical processes attendant upon germination and vegetation in plants and on respiration in animals, afford a very interesting analogy between the operations of these two classes of organised beings.

Mineral Kingdom.

The benefits to be derived in scientific medicine, from the investigation of the inorganic kingdom of nature, are not less than those which result, as we have endeavoured to shew, from the study of the other two kingdoms. The connection between epidemic diseases and particular kinds of weather, whether as occurring regularly at particular periods of the year, or as varying in different years without any fixed rules, is a subject of medical consideration which may be expected to receive some light from the science of meteorology. The influence of climate upon the human economy, and particularly in the production, modification, and removal of diseases, confers a great share of importance on the investigation of all those circumstances upon which the character of a climate depends; the atmosphere, the soil, and the waters which flow from it, or with which it may be surrounded. A knowledge of the principles of meteorology and of geology is essential therefore to any correct views of Medical Topography.

Practice.

The fascination exercised over many minds by those various branches of natural knowledge, which we have here represented as the auxiliary sciences of medicine, have led some to regard with much jealousy, invitations or recommendations to medical men to engage in their study. This jealousy, however, seems to arise from a total misconception as to the manner in which they ought to be prosecuted when considered as branches of a medical education. To acquire a knowledge of the details of any one of them is probably sufficient to occupy the time of a person of ordinary application; and would consequently be to most persons inconsistent with the prosecution of studies of a more strictly medical character. But without the sacrifice of any knowledge essential to his profession, a medical man may attain a competent acquaintance with the general principles of these auxiliary sciences sufficient to enable him to understand their bearings upon medicine. In possessing a knowledge of these principles, he holds an instrument in his hand by which he may be able to work out any part of the details of these sciences that may seem capable of throwing light upon any point of medical doctrine or practice to which his attention may happen to be particularly called. To the extent that we have hinted, therefore, a medical education cannot be considered as complete which does not comprehend an acquaintance with these several auxiliary sciences. "It is not possible," says an intelligent author, whose country is apparent from his illustrations, "that a medical man should know botany like De Jussieu or Richard; chemistry like Vauquelin, Thénard, and Bouillon La Grange; physics like Biot and Gay-Lussac; mineralogy like Haüy; and natural history like Cuvier and Dumeril: but a knowledge of the elements of these sciences is indispensable to him; and immense as is the domain of medicine alone, he may very well, if he chooses, find time to make some excursions on neighbouring territories."

Medicine as an art. Surgery and Physic

In the exercise of Medicine as a practical art, the second point of view in which we have said it must be considered, three branches of the profession independently of pharmacy or the preparation of medicinal substances, have long been recognised; surgery, physic, and midwifery. To the domain of Surgery have been referred, besides injuries produced by agents operating on the external surface of the body, those diseases which, in addition to the ordinary means of cure, require the assistance of the hand, and are thence called chirurgical or surgical diseases; and to that of Physic, those diseases which may be cured, without the employment of manual operation. An attempt has been made to identify this division of diseases into surgical and medical, with those into local and constitutional, and into external and internal diseases. But it must always be remembered that the different textures, systems, and organs of which the human body is composed, are arranged so as to form an entire whole, the various parts of which act on, and are reciprocally acted on by one another. Although, therefore, some morbid affections occurring on particular parts of the external surface of the body, and consequently regarded as surgical, may produce no disturbance of the general economy, or attended with constitutional symptoms too slight for observation, yet there are external or local diseases which

Practice. often produce constitutional effects of the most alarming and fatal nature. Symptomatic and hectic fever, locked-jaw, convulsions, and epilepsy, may be mentioned as some of the more remarkable constitutional affections which are produced by the action of local diseases. And on the other hand, internal and constitutional diseases, which are consequently regarded as falling under the province of the physician, occasionally become attended in their progress with external or local affections requiring surgical interference; as when abscesses occur in the progress of fever, or fistula in the progress of consumption; or when pleurisy terminates in empyema, or disease of the liver in ascites or œdema. "It is in the knowledge of these and of similar diseases, that the boundaries which divide physic from surgery meet and are lost in each other; for whatever distinctions convenience or custom may have introduced among the practitioners of the healing art, there is no foundation for these distinctions either in the nature of diseases, or in the knowledge that every medical practitioner should possess of the appearances which different diseases exhibit, and of the means by which they are to be removed. Division of labour may, indeed, in medicine as in the other practical arts of life, be attended with many advantages to society; but in learning and in teaching the elements of physic and of surgery, it must never be forgotten that they are branches of the same art, have had the same origin, are governed by the same principles, and pursue entirely the same object." It is not, indeed, in the kind or in the extent of their knowledge, that the physician and surgeon of the present day are to be distinguished; but in the latter's being possessed of, and accustomed to exercise those powers of head and hand upon which the skilful performance of difficult or dangerous operations must depend.

No topic ever gave rise to more acrimonious controversies, than the question as to the necessity or expediency of physic and surgery being practised as separate and distinct professions; and, where such a separation has been made, as to the proper relation of the practitioners of these professions, to one another. But, whilst the practitioners have been engaged in discussing, the public has settled the matter on its own judgment, and in the manner best suited for its own convenience. Every thing seems to intimate that at the present day there exists a strong disposition on the part of a large portion of the public, to entrust the charge of their health, and of that of their families, under whatever kind of malady they may suffer, to some one practitioner in particular; and in the event of there appearing obscurity, or reason for apprehension in the complaint, then to avail themselves of the additional advice or assistance of some person or persons supposed to have directed their attention in a particular degree to cases of a similar description. Accordingly, it is only in cities that are the residence or the resort of large numbers of people, that any medical men can attempt to confine their practice to the treatment of medical or surgical cases exclusively; and even in such situations, the great bulk of practitioners must, like their brethren in smaller towns and rural districts, to a greater or less degree, combine the exercise of all branches of practice. It is by having sagaciously perceived, and judiciously availed themselves of this disposition on the part of the public, that the apothecaries of England have obtained so extensive and firm a footing in medical practice in that country.

Midwifery Under the department of Midwifery, is included every thing connected with the process of child-bearing, and the diseases to which women are subject, both during gestation and after parturition: and as the class of practitioners who occupy themselves especially with the practice of midwifery, are favourably circumstanced for becoming acquainted with those diseases peculiar to women, which are unconnected with child-bearing, as well as with the diseases of infants; it has become usual to include these diseases also in systematic views of this department of medical practice. Practice.

It is satisfactory to find that the medical corporations of this country have at last extended the right hand of fellowship to the practitioners of midwifery. Nothing, indeed, could be more ridiculous than the grounds upon which they have hitherto held its exercise to be a disqualification for corporate association. If there be any class of practitioners, of whom, more than another, it is desirable that to great practical skill, and to an extended acquaintance with all departments of medical science, they should unite the greatest delicacy of feeling, and refinement of manners, it certainly must be those engaged in this branch of the profession. It would be strange, therefore, if the public, for the gratification of some absurd notion of professional etiquette relative to manual operation, were to sanction with its approbation the affixing a stigma to a profession in which such qualifications are desirable.

In reference to medical practice considered as an object of legislative regulation, it may not be out of place to remark here, that there are two principal modes in which legislatures have endeavoured to improve the profession of medicine. The first of these has been by making arrangements for the conferring of distinctions upon persons, who, from the education they have received, and the examinations they have undergone, may be considered as competent to exercise the different branches of the art. The second mode, and that which it has hitherto been the great object of all plans of medical reform in this country to enforce, has been the suppression of unlicensed and incompetent practitioners, by penal enactments. That the pointing out the competent is a just and expedient interference on the part of the legislature, does not seem to admit of doubt. But the suppression of the incompetent seems not only questionable in respect of justice, but incapable of being enforced in a country politically constituted like this, so long as there exists a taste for quackery in the public mind. It is as regards the employer rather than the employed, that the justice of this interference may be doubted; for there seems no good reason why, if a person prefers the doctor of nature, as the quack is supposed to be, to the doctor of the schools, the legislature should control him in his choice. It has usually been pretended, indeed, that the object of such enactments has been the protection of the poor and the ignorant against the unskilful. But the exception generally made in favour of gratuitous practice, suggests a doubt whether those at whose instigation the legislature has sanctioned such enactments, may not have been influenced in demanding them by other less ostensible motives. Experience seems to have shewn that the prosecution of quacks, particularly when this has been conducted at the instance of medical corporations, so far from suppressing has rather had a tendency to strengthen the public taste for quackery. The only mode in which it can be expected that this taste will be overcome, is by disseminating among the community sound views of health, disease, and remedies, so as to enable them to appreciate the pretensions of those who profess to accomplish things which it requires only a little information to know to be impossibilities. So long, however, as the taste shall continue to prevail, it is surely much better that it should find vent in the employment of professed quacks, than be directed to the corruption, we would say prostitution, of regular practitioners. The legitimate means by which unlicensed practitioners may be discouraged by the legislature, are, *first*, their not being allowed to hold public appointments; *second*, their having no legal claim to remuneration; and, *third*, their being punished in case of their assuming a title which they have not legitimately acquired. Further than these measures, it is not to the legislature that the medical profession should look for assistance in suppressing quackery and quacks.

Medical legislation.

Practice. It is impossible to allude to the interference of the legislature in matters relating to medical education and practice, without congratulating the medical profession and the public in general, on the very full inquiry recently instituted into these subjects under the authority of the House of Commons. The number of contending interests, real or supposed, requiring to be consulted, and the jealousy felt by some of the parties, of undue partialities being entertained in influential quarters, in favour of their competitors, rendered it proper to receive a mass of oral and written evidence of so great extent that some time has necessarily been consumed in its digestion. We venture to hope that the intelligent and indefatigable chairman of the committee, (to whose extraordinary perseverance in expiscating information, and patience in receiving what was offered, we have much pleasure in bearing our humble testimony,) will ere long propose a system of medical legislation in which the principles shall be fully recognised, that whatever distinctions or divisions, political or medical, may formerly have existed, or there may still in some minds be the wish to maintain, the different branches of medicine form only one science, and the different parts of the British dominions only one empire.

Medical jurisprudence

In the intercourse of society, many questions arise which, though not bearing immediately on the treatment of diseases, are yet so connected with the consideration of the human economy in its healthy or diseased states, that the advice and opinions of medical men are very frequently required respecting them. Of these, some relate to the means of detecting crimes; others to the capability of individuals for discharging the social or civil functions of life; others to the means of preserving the public health, and so forth. It is the object of Medical Jurisprudence to explain at least the general principles by which medical men should be guided in forming their opinions on the particular points that may be referred to their decision. For the proper cultivation of this branch of study, there is no single department of medical science a knowledge of which is not necessary. Chemistry, materia medica and pharmacy, anatomy and physiology, surgery, physic and midwifery, must all contribute their several lights for the elucidation of many of those medico-legal questions on which the medical man is called to pronounce a judgment; and we have but too often reason to lament the deep and painful obscurity in which, notwithstanding all possible assistances, many of these questions are still left involved.

No branch of medical jurisprudence has made more rapid progress than that which relates to the power of detecting, by chemical reagents, the presence of poisonous substances, not only in the various media in which they may be administered, but also subsequently to their introduction into the body, and their diffusion through its different fluid and solid parts. But whilst toxicology, or the consideration of poisons, has been thus greatly advanced by the improvement and extension of chemical knowledge, it has likewise received most important contributions from branches more strictly medical. The symptoms to which poisons give rise during life, and the changes which they produce upon the surfaces with which they come immediately in contact, as well as on more remote organs, and which are discoverable after death, have been investigated with great attention, with a view to their discrimination from similar symptoms and changes occurring as consequences of disease.

Morbid anatomy has rendered important services to medical jurisprudence by directing attention to those appearances in the different textures and organs of the body, which are the consequences of changes occurring subsequently to death or immediately previously to it, and by teaching medical men to distinguish these pseudo-morbid appearances from those that are the genuine products of disease, or of injury inflicted during life.

Practice. To surgery medical jurisprudence looks for a determination as to the amount of external violence of different kinds by which death may be occasioned; and particularly for ascertaining the circumstances upon which it may depend, that injuries apparently trivial in their degree may give rise to most injurious or even fatal consequences. It is the province of the surgeon also to endeavour to judge, in cases of injury depending on external violence, as to the nature of the means or instrument by which the injury had been produced.

The medico-legal questions which fall more particularly under the consideration of those who are engaged in the practice of midwifery, are many of them of an extremely delicate nature in a moral point of view, and extremely difficult of determination. As illustrations of these may be mentioned the questions as to the variations in the length of time during which gestation may continue in the human species; as to the earliest period of its uterine existence at which a human fœtus can live, when separated from its mother naturally or by artificial means; and as to the marks by which it can be determined whether an infant found dead, had or had not survived the period of its birth.

No class of medico-legal questions proves more frequently perplexing than those in which it is necessary to pronounce a judgment on the mental sanity or insanity of an individual; to determine whether he labours under such a degree of mental weakness or aberration, as to be incapable of managing his own affairs, or unfit to be trusted with the control of his own actions, or as to render some restraint upon his proceedings proper or necessary for the safety of others. The difficulties in cases of this kind are most materially increased by the circumstance that the mental aberration may implicate only one small portion of the intellect, the individual speaking and acting rationally except in so far as he may be misled by a single hallucination; and they are greatly augmented also by the circumstance, that persons thus insane upon particular topics, not unfrequently possess the power, when suspicious of being objects of attention, of concealing the particular delusion under which they labour.

So far as medical jurisprudence bears on the preservation of the public health, it must, like hygiène, of which, indeed, when viewed in this light, it forms a part, be dependent on the study of ætiology. The circumstances under which human contagions or terrestrial miasmata are engendered; the laws according to which their diffusion is regulated, and the means best suited for preventing their propagation; the influence which other effluvia exert upon the economy, as, for example, those produced in the operations of manufactories of different kinds; the circumstances under which particular provisions become unwholesome or poisonous;—these and many other ætiological questions, medical men are constantly liable to have referred to them by the public authorities, either with a view to the adjustment of private rights, or to the preservation of the health of communities.

Conclusion

The whole range of Medicine, it thus appears, may be divided into two parts; the scientific or theoretical, and the empiric or practical. The theoretical part again naturally divides itself, so far as regards the study of the human economy, into four branches: 1st, a knowledge of the structure of the body in the state of health, or Anatomy; 2d, a knowledge of the functions of the economy in the state of health, or Physiology; 3d, a knowledge of all that relates to diseased structure and diseased function, or General Pathology; and, 4th, a knowledge of the powers of remedies, or General Therapeutics. The practical part of medicine may also be marked out into four divisions: the 1st, comprehending Surgery, or the consideration of external diseases and injuries; the 2d, Physic, or the consideration of internal diseases; the 3d, the principles of Midwifery; and

Medici. the 4th, the application of medicine to police and jurisprudence. To the several articles Anatomy, Physiology, Pathology, Therapeutics, Surgery, Nosology, Midwifery, and Medical Jurisprudence, we must refer our readers for further information on each of these branches of medicine.

We cannot conclude this brief outline of the different branches of Medicine considered as a science and as an art, better than in the language of one whose words we have already several times had the pleasure to quote. "A person may possess," says M. Prunelle, "extensive information in medicine, and still not be able to treat a disease. This in itself establishes an essential difference between the science of medicine and the art of curing, the latter of which consists in the talent of applying that science to the preservation or to the restoration of health. The science exists, therefore, independently of the art; and the art is exercised, sometimes without serious injury, by persons to whom the science is almost unknown. The true physician combines in himself the knowledge of the man of learning and the skill of the practitioner. Imbued with the true principles of the science, accustomed to reflect on what he sees or hears, he is not contented with perceiving the outward phenomena of diseases; he remounts to their causes; he connects these causes with the phenomena which they have produced; he seeks amongst these phenomena for those which suggest the employment of curative means; and if he does not succeed in rendering himself a reason for all parts of his conduct, a kind of instinct, a secret presentiment, warn him at least of what he ought to do. The mere practitioner, on the contrary, I should rather say the empiric, imitates, without scrutinizing the reasons for it, all that he has seen practised; he is guided by an analogy frequently deceitful, to treat on the same plan diseases which have the same external appearance; he considers, as it were, only their bark, and if the habit of seeing, joined with a natural talent for observation, enable him sometimes to imitate successfully, he is unconscious of what he is himself accomplishing; he is never struck with those sudden inspirations that are the privileges of medical genius, which nature reserves for those only who are able to unite with learning, the facility of promptly analysing all the elements of a disease, and calculating all its probabilities." Medici.

(L.L.L.L.)

MEDICI, Cosmo de', was born in the year 1389, and was in the prime of life, at the death of his father Giovanni. His conduct was distinguished for urbanity and kindness to the superior ranks of his fellow-citizens, and by a constant attention to the wants of the lower class, whom his munificence abundantly relieved. His prudence and moderation, however, could not repress the ambitious designs of the rival families; and in 1433, Rinaldo de Albizi, at the head of a formidable party, carried the appointment of the magistracy. On returning from his country-seat he was seized upon by his adversaries, and committed to prison. But the conspirators not agreeing as to the proper method of dispatching their prisoner, one Peruzzi recommended poison, which was heard by Cosmo, who refused to take any other sustenance than a small portion of bread. In this dismal situation he remained four days, shut up from all his kindred and friends, and he soon expected to be numbered with the dead. But the man employed to take him off, unexpectedly proved his friend. Malavolta, the keeper of the prison, relented, and declared that he had no just reason to be alarmed, as he hesitated not to eat of every thing which was brought him.

His brother Lorenzo, and his cousin Averardo, raised a considerable body of men in Romagna and other districts; and being joined by the commander of the republican forces, they marched to Florence to relieve him. A decree was obtained from the magistracy, by which he was banished to Padua for ten years, and his brother to Venice for five, whilst several of their relations shared a similar fate. Padua was in the dominions of Venice, and before he reached it he received a deputation from the senate, promising him their protection and assistance in whatever he should desire. He experienced the treatment of a prince rather than that of an exile, as they entertained the highest expectations from his great commercial knowledge. From this period his life may be considered as one continued scene of uninterrupted prosperity, and his family received an education equal to that of the greatest potentates. In his public and private charities he was almost unbounded, and perhaps possessed more wealth than any single individual in Europe at that period. In the promotion of science and the encouragement of learned men he was truly exemplary, and by his conduct in this respect he acquired the greatest honour and esteem.

His fostering hand cherished the arts as well as the sciences; and architecture, sculpture, and painting, all flourished under his powerful protection. The countenance he shewed to these arts was not such as their professors generally receive from the great; for the sums of money which he expended upon pictures, statues, and public buildings, appear almost incredible. When he approached the term of his mortal existence, his faculties were still unimpaired; and not many days before he died, he requested Ficino to translate from the Greek the treatise of Xenocrates on death. He died on the 1st of August 1464, at the age of seventy-five, and gave strict injunctions, that his funeral should be conducted with as much privacy as possible. By a public decree he was honoured with the title of Father of his Country; an appellation which was inscribed on his tomb, and declared, by competent judges, to be founded in real merit.

Medici, Lorenzo de', styled, with great propriety, the *Magnificent*, was the grandson of Cosmo, and about sixteen years of age at his decease. In 1469 his father died, and he succeeded to his authority as if it had constituted a part of his fortune. In the year 1474, Lorenzo incurred the displeasure of the pope on account of the opposition he offered to some papal encroachments on the petty princes of Italy, and for this reason the pontiff deprived him of the office of treasurer of the Roman see, which he conferred upon one Pazzi, connected with a Florentine family, the interest of which he thus secured, and intended to sacrifice Lorenzo and Juliano to his private revenge. Their assassination was fixed for Sunday the 26th of April 1478, and the cathedral was the place in which a monster of an archbishop had resolved to murder them at the instigation of the pope. When the people saw one of their favourites, Juliano, expiring, and the other, Lorenzo, covered with blood, their rage was not to be expressed in language. The interference of the magistrate was finally victorious, and he had the courage and virtue to hang the archbishop from one of the windows, arrayed in his pontificial robes, which made Florence resound with acclamations of joy.

Lorenzo was delivered from that part of the cathedral to which he had fled for refuge, and triumphantly carried home, where his wounds were attended to by men of ability. His friends in the mean time pursued the conspirators, and spared none who happened to fall in their way. In a word, the generality of them were either hanged or decapitated, and very few had the good fortune to escape the vengeance of their pursuers. To the honour of Lorenzo, he exerted all his influence to prevent the indiscriminate massacre of his enemies, and restrain the just indignation of the people, begging that they would trust the magistrates with the punishment of the guilty; and the respect in which

Medina. he was held had the effect of restraining the vengeance of popular indignation.

No sooner had hostilities ceased between Pope Sixtus and the Florentine republic, than Lorenzo began to develope plans for securing the internal peace and tranquillity of Italy. But the life of this great man was again brought into imminent danger by the intrigues of Cardinal Riario, and some Florentine exiles, who determined to assassinate him in the church of the Carmelli, on the festival of the Ascension in 1481; but the plot was happily discovered, the conspirators were executed, and after this time Lorenzo seldom went abroad without being surrounded by a number of friends in whom he could securely confide.

When we attentively examine the character of Lorenzo, it will not perhaps appear astonishing, that Italy, Christendom, and even the Mahommedans themselves, honoured him with the most flattering approbation. The Prince of Mirandola chose Florence as the place of his residence entirely on account of this remarkable man, and there ended his mortal career. To a most engaging person Lorenzo added almost every other accomplishment. He was declared to be unrivalled in chivalry, and one of the most eminent orators that the world had in any age produced. When Ferdinand, king of Naples, was informed of his death, he observed, "This man has lived long enough for his own glory, but too short a time for Italy." He died on the 8th of April 1492, amidst a number of his weeping friends, who appeared deeply conscious of the irreparable loss sustained by their country. His life and character, and the general history of his age, form the subject of a well known and elegant work by the late Mr. Roscoe.

MEDINA, a city of Arabia, and one of the holy cities of the Mahommedans, celebrated for affording refuge to Mahommed in his flight from Mekka, for his residence in it, and for his tomb, to which the devout hadjis still resort, although its visitation is not considered as a duty, nor necessary part of the Mahommedan pilgrimage. It is situated on the edge of the great Arabian desert, close to the chain of mountains which traverses that country from north to south, and forms a continuation of the chain of Lebanon. The town is built on the lowest part of the plain, and it is enclosed on three sides with gardens, trees, and walks, leaving only that part of the plain open to the view, which is on the side of the road towards Mekka, where the rocky nature of the ground renders cultivation impossible. It is mentioned by Burckhardt, (*Travels in Arabia*, vol. ii. p. 148,) as one of the best built towns which he saw in the east, ranking in this respect next to Aleppo. The houses consist generally of two stories; they are built of stone, and have flat roofs. The stone being of a dark colour, the streets present rather a gloomy aspect, and are, with some exceptions, very narrow, being often only two or three paces across; a few of the principal are paved with large blocks of stone, a comfort seldom found in the Arabian towns. Medina is divided into the interior town and the suburbs; the interior forming an oval of about 2800 paces in total circuit, ending in a point. The castle is built at the point, on a small rocky elevation, and the whole is enclosed by a thick stone wall, between thirty-five and forty feet in height, flanked by about thirty towers, and surrounded by a ditch, formed by the Wahabees, and now in many places filled up. Three fine gates lead into the town, one of them the finest town gate, according to Burckhardt, that he had seen in the east. The principal street of Medina, which is also the broadest, leads from the Cairo gate to the great mosque. This street contains most of the shops. Another considerable street runs from the mosque to the Syrian gate; but many of its houses are in ruins. This contains also a few shops, but none are found in other parts of the town; and in this respect Medina differs from Mekka, which is one continued market. At present, especially since the great pilgrimage was interrupted by the incursions of the Wahabees, the town has a desolate appearance; the houses are suffered to go to decay; the crowd of visitors to whom they were in the habit of letting their apartments having diminished, the owners have no prospect of being reimbursed for any extra expense which they may lay out. Ruined houses, and walls wanting repair, are seen in every part of the town; and Medina, like most eastern towns exhibits but a faint image of its ancient splendour. On the west and south of the town, extend the suburbs, which cover more ground than the town itself. An open space intervenes, narrow on the south side, but widening on the west, before the Cairo gate, where it forms a large public place called Monakh, where the caravans alight, and which is always crowded with camels and Bedouins. Here are erected huts and sheds, in which provisions are sold, and a number of coffee huts which are beset all day with visitors. The side of the suburbs which fronts this place has no wall; but on the outside they are enclosed by a wall of inferior size and strength to the interior town wall. Four gates, or rather wooden doors, none of them of any strength except that leading from the Cairo gate, which is larger and better built than the rest, lead into the suburbs. These consist of large court-yards, with low apartments built round them, on the ground-floor, and separated from each other by gardens and plantations, with the exception of the west side directly opposite the Cairo gate, where the suburb consists of regular and well-built streets, with houses resembling those of the interior of the town. Many of the richer inhabitants have their summer houses in these quarters, where they pass a month in the date harvest. Every garden is enclosed by mud walls, and several narrow by-lanes, just broad enough for a loaded camel to cross the suburbs in every direction. The suburbs are principally inhabited by all the lower classes of the town, by many of the Bedouin Arabs who have become settlers there, and by all who are engaged in agriculture. The town is divided into separate hamlets, called hosh, containing thirty or forty families, who often in times of unsettled government, are engaged in desperate feuds with one another. Medina.

Few large public buildings are found within the precincts of the town. The great mosque, containing the tomb of Mahommed, is the only temple. A fine public school, called Medrese el Hamdye; a similar one near the mosque; a large corn magazine, enclosing a wide yard in the southern quarter of the town; and a bath not far distant from it, built in the year of the hejira 973 (A.D. 1678,) by Mahommed Pasha, are all the public buildings that were observed by Burckhardt. The want of public buildings, however, in the town is compensated by the numerous pretty private habitations, having small gardens with wells, the water of which is used in irrigation, and fills marble basins, round which in summer time, the owners pass the hours of noon under lofty shades. The castle already mentioned is surrounded by very strong walls, and several high and solid towers. It contains sufficient space for 600 or 800 men; has many arched rooms bomb proof; and would be impregnable against any Arabian force, being built upon a rock, which cannot be undermined. But it would not hold out for any time against European artillery.

The great ornament of Medina, which nearly raises the sanctity of the city to a level with that of Mekka, is the great mosque containing the tomb of Mahommed, which is situated towards the eastern extremity of the town; it is inferior in its dimensions to the mosque at Mekka, being 165 paces in length, and 130 in breadth. It is built on much the same plan of an open square, surrounded on all sides by covered colonnades of ten, four, and three rows, on the south, west, and north sides, with a small building in the centre of the square. The roof of the colonnade consists of a number of small domes, white-washed on the outside, in the same manner as those of Mekka. The interior walls are also white-

Medina. washed except the southern one, which is cased with slabs of marble up to the top, and has several rows of inscriptions in gilt letters. The floor under the collonades is coarsely paved, excepting in those parts nearest to the tomb of Mahommed, where the pavement is mosaic, forming one of the best specimens of that kind of workmanship to be seen in the East. Large and high windows, with glass panes, the only instance of glass in windows that Burckhardt saw in Arabia, some of them of fine painted glass, admit the light through the southern wall. Near the south-east corner stands Mahommed's tomb, detached from the walls of the mosque, and enclosed by an iron railing painted green, which is entered by four gates. Within the inclosure is a curtain carried wholly round it, which is said to cover a square building of black stones, supported by two pillars, in which are the tombs of Mahommed and his two earliest friends and immediate successors, Abou Bekr and Omar. These tombs, as far as Burckhardt could learn, are covered with precious stuffs; and here were deposited all sorts of vessels set with jewels, ear-rings, bracelets, necklaces, and other ornaments, brought as presents from all parts of the empire, by the rich pilgrims as they passed through Medina. The whole formed a collection of considerable value; though it was, no doubt, occasionally pillaged by the pious priests who are appointed to the service of the temple, in the same manner as they stole the golden lamps from the mosque at Mekka. Amongst other curious relics, a copy of the Koran in Cufic characters, which belonged to Othman ibn Affan, was deposited here. When Medina was taken by the Wahabees, their chiefs seized all the golden vessels. Saoud, who penetrated behind the curtain, took every thing that was valuable, and amongst other precious articles, the Cufic manuscripts of the Koran, and a brilliant star set in diamonds and pearls which was suspended directly over the prophet's tomb. Several of the golden vessels were re-purchased by Toussoun Pasha, the son of Ali Pasha, when he entered Medina in his war against the Wahabees, and replaced in their original situation. The door between the curtain and the railing is inlaid with various coloured marble in mosaic; and here are suspended glass lamps which are lighted every evening, and remain burning all night. The whole of this inclosure is covered with a fine lofty dome, which the Wahabees determined to destroy; but it was so strong that it resisted all their efforts to destroy it. The dome is surmounted with a globe and crescent both glittering with gold. A wooden partition, about eight feet in height, and richly painted with arabesque, runs from the western side of the railing across the mosque, parallel with the south wall, and separates the holy place called El Rodha, or the garden of paradise, from the common passage. Here, on the carpet, the congregation assembles, this being the favourite spot for prayers. The entrance has a splendid appearance; but, says Burckhardt, it is all tinsel decoration, and has a paltry appearance compared with the catholic churches of Europe. The mosque is entered by four gates; and its service is entrusted to forty or fifty eunuchs, who have, like their brethren in Mekka, large stipends annually remitted from Constantinople. Medina is abundantly supplied with water, though not of a very good quality, by a fine subterraneous canal, carried hither from the village of Koba, about two miles distant; and water is everywhere found by digging to the depth of twenty-five or thirty feet. A supply of water is also derived from a torrent, which flows from south to north, passing across the suburbs. In 1804, Medina surrendered to the Wahabee arms; but was again besieged and taken in 1812, by the Egyptian army of Ali Pasha, under his son, Toussoun Bey, when a thousand of the inhabitants were massacred in the streets. Yembo is the port of Medina, from which it is distant 160 miles.

Medina, a town and fort of the island of Bahrein, near the Arabian shore of the Persian Gulf, which carries on a considerable trade with Bassora and the other ports of this sea. Near it is a bank containing the finest pearls in the world. Medina Meditation

Medina Celi, an ancient town of Spain, in Old Castille, and capital of a considerable duchy of the same name; it is situated near the river Xalon, in W. Long. 2. 9. N. Lat. 41. 15.

Medina de-las-Torres, a very ancient town of Spain, in Estremadura, with an old castle, and the title of a duchy. It is situated on the confines of Andalusia, at the foot of a mountain near Badajoz.

Medina-del-Campo, a large, rich, and ancient town of Spain, in the kingdom of Leon. The great square is very fine, and adorned with a superb fountain. It is a trading place, enjoys great privileges, and is situated in a country abounding with corn and wine. W. Long. 4. 20. N. Lat. 41. 22.

Medina-del-rio-Seco, an ancient and rich town of Spain, in the kingdom of Leon, with the title of a duchy; it is situated on a plain, remarkable for its fine pastures. E. Long. 4. 33. N. Lat. 42. 8.

Medina Sidonia. A city in the province of Andalusia in Spain. It is the head of a duchy, and with the surrounding country is the property of a duke, in whom are united the estates and titles of Medina Celi, and Medina Sidonia. The city is built on the side of a high mountain, from whence, owing to the translucency of the atmosphere, it has a fine view of the city and bay of Cadiz, and the populous towns and rich districts around it. It contains 5000 inhabitants.

Medina, Sir John, an eminent painter, was son of Medina de l'Asturias, a Spanish captain, who settled at Brussels, where the subject of this notice was born in 1660. He was instructed in painting by Duchatel, under whose direction he made great progress; and applying himself to the study of Rubens, he made that eminent master his principal model. He painted both historical subjects and portraits, and was held in extraordinary estimation by most of the princes of Germany, who distinguished his merit by several marks of honour. He married young, and came into England in 1686, where he painted portraits for several years with great reputation, exhibiting remarkable freedom of touch, with a delicate management of tints, and producing a strong resemblance to the originals. The Earl of Leven encouraged him to go to Scotland, and procured him employment there to the extent of £500. He went thither, carrying a large number of bodies and postures, to which he afterwards painted heads. He returned to England for a short time, but went back to Scotland, where he died, and was buried in the churchyard of the Greyfriars at Edinburgh, in 1711, aged fifty-two. He painted most of the Scotch nobility. Medina was knighted by the Duke of Queensberry, lord high commissioner, and was the last knight made in Scotland before the Union.

MEDINE, an Egyptian piece of money of iron silvered over, and about the size of a silver threepenny piece.

MEDIOLANUM, now Milan, an ancient city, the capital of the Insubres, built by the Gauls, on their settlement in that part of Italy; it was a *municipium*, a place of great strength, and also a seat of the liberal arts, whence it had the name of *Novæ Athenæ*.

MEDITATION, an act by which we consider any thing closely, or in which the soul is employed in the search or consideration of any truth. In religion it is used to signify a consideration of the objects and grand truths of the Christian faith. Mystic divines make a great difference between *meditation* and *contemplation*. The former consists in discursive acts of the soul, considering methodically and with attention the mysteries of faith and the precepts of morality, and is performed by reflections and reasonings, which leave behind them manifest impressions on the brain. But the

Mediterranean || Medusa.

purely contemplative have no need of meditation, as they see all things in God at a glance, and without any reflection. When a man, therefore, has once quitted meditation, and arrived at contemplation, he returns no more; and, according to Alvarez, never resumes the oar of meditation, except when the wind of contemplation is too weak to fill his sails.

MEDITERRANEAN, something enclosed within land, or that is remote from the ocean, properly so called.

MEDITERRANEAN is more particularly used to signify that large sea which flows between the continents of Europe and Africa, entering by the straits of Gibraltar, and reaching into Asia, as far as the Euxine or Black Sea and the Palus Mæotis.

The Mediterranean was anciently called the Grecian Sea and the Great Sea. It is now cantoned out into several divisions, which bear several names. To the west of Italy it is called the Ligurian or Tuscan Sea; near Venice, the Adriatic; towards Greece, the Ionian and Ægean; between the Hellespont and the Bosphorus, the White Sea; and beyond the Bosphorus the Black Sea.

MEDITRINALIA, a Roman festival in honour of the goddess Meditrina, observed on the 30th of September. Both the deity and the festival were so called *a medendo*, because on this day they began to drink new wine mixed with old by way of medicine. The mixture of wines, on this festival, was drunk with much form and solemn ceremony.

MEDIUM, in *Logic*, the mean or middle term of a syllogism, being an argument, reason, or consideration, concerning which we affirm or deny any thing; or, it is the cause why the greater extreme is affirmed or denied of the less in the conclusion.

MEDIUM, in *Arithmetic*, or arithmetical medium or mean, called in the schools *medium rei*, is that which is equally distant from each extreme, or which exceeds the lesser extreme as much as it is exceeded by the greater, in respect of quantity, not of proportion. Thus 9 is a medium between 6 and 12.

Geometrical MEDIUM, called in the schools *medium personæ*, is that where the same ratio is preserved between the first and second as between the second and third terms, or that which exceeds in the same ratio or quota of itself, as it is exceeded. Thus 6 is a geometrical medium between 4 and 9.

MEDIUM, in *Philosophy*, that space or region throughout which a body in motion passes to any point. Thus æther is supposed to be the medium through which the heavenly bodies move; air, the medium in which bodies move near our earth; water, the medium in which fishes live and move; and glass is also a medium of light, as it affords it a free passage. That density or consistency in the parts of the medium, by which the motion of bodies in it becomes retarded, is called the *resistance of the medium*, which, together with the force of gravity, is the cause of the cessation of the motion of projectiles. Sir Isaac Newton considers it probable that, besides the particular aërial medium in which we live and breathe, there is another more universal one, which he calls an *æthereal medium;* vastly more rare, subtle, elastic, and active, than air, and freely permeating the pores and interstices of all other mediums, and diffusing itself throughout the whole of creation, and by the intervention of which it is that, according to him, most of the great phenomena of nature are produced.

MEDIUM, in *Optics*, signifies any substance through which light is transmitted.

MEDUCK, a town of Hindustan, and chief town of a district of the same name, which is situated about the 18th degree of north lat. The town is fifty miles NNW. from the city of Hyderabad. Long. 78. 20. E. Lat. 17. 50. N.

MEDUSA, in fabulous history, one of the three Gorgons, and daughter of Phorcys and Ceto. She was the only one of the Gorgons who was subject to mortality; and she was celebrated for her personal charms and the beauty of her locks. Neptune became enamoured of her, and obtained her favours in the temple of Minerva. But this violation of the sanctity of the edifice provoked Minerva, and she changed the beautiful locks of Medusa, which had inspired Neptune's love, into serpents, the sight of which turned the beholders into stones; Perseus, however, armed with Mercury's axe, with which he killed Argus, cut off Medusa's head, from the blood of which sprang Pegasus and Chrysaor, together with the innumerable serpents that infest Africa. The conqueror placed Medusa's head on the ægis of Minerva, which he had used in his expedition; and the head still retained the same petrifying powers as before.

Medway || Megalesia.

MEDWAY, a river of England, which rises in the Weald of Sussex, and entering Kent near Ashurst, runs by Tunbridge, and thence continues its course towards Maidstone. It is navigable for large ships to Rochester bridge, and thence for vessels and barges to Maidstone, the tide flowing up to that town. The distance between the mouth of this river, where the fort at Sheerness is erected, and Rochester bridge, is between sixteen and eighteen miles. In this part of the river the channel is so deep, the banks so soft, and the reaches so short, that it is one of the best and safest harbours in the world; and ships of eighty guns ride afloat at low water, within musket-shot of Rochester bridge. Nor is there a single instance upon record, that any of the royal navy ever suffered here by storms, except in the dreadful tempest which happened in November 1703, when the *Royal Catherine* was sunk and lost.

MEDYN, a circle of the Russian province Kaluga, extending from N. lat. 54. 28. to 55. 19., and from E. long. 34. 42. to 35. 46., being 1328 square miles, with a population of 76,800 persons. The capital is a town of the same name, 583 miles from Petersburg; it is situated on the river Medynka, and has 195 houses, with 1250 inhabitants. A battle was fought near it, on the 14th of October 1812, when the French were defeated. Lat. 55. 4. Long. 37. 45. E.

MEEGHEOUNG-YAY, a town of the Birman empire, and province of Ava. It is situated on the bank of the Irrawaddy river, and it carries on a considerable traffic in grain and oil. It stands in the midst of a fertile and well cultivated country. Long. 94. 50. E. Lat. 19. 53. N.

MEERAT, a town of Hindustan, in the province of Ajmeer, district of Zundpoor, thirty-six miles west from the city of Ajmeer. Long. 74. 14. E. Lat. 26. 35. N.

MEERCASSERAI, a small town of Bengal, and district of Chittagong, thirty-five miles N. by W. from the town of Islamabad. Long. 90. 30. E. Lat. 22. 48. N.

MEERJAOW, a town of Hindustan, in the province of Cascara, which stands upon an inlet of the sea, and is supposed by Dr. Robertson to have been the Musiris of the ancients. It was nearly destroyed by Hyder Ali, when he invaded the province in 1773. The forests in the neighbourhood abound with teak timber; they also produce black pepper spontaneously, and cassia and wild nutmegs are common. It is eighty miles SSE. from Goa. Long. 74. 36. E. Lat. 14. 27. N.

MEGALE POLIS, or MEGALOPOLIS, in *Ancient Geography*, a town of Arcadia, built under the auspices of Epaminondas, after the battle of Leuctra, many inconsiderable towns being joined together in one great city, the better to withstand the Spartans. According to Strabo it was the greatest city of Arcadia.

MEGALESIA, and MEGALENSES LUDI, feasts and games celebrated by the Romans in honour of Cybele or Rhea, the mother of the gods, on the 12th of April, and famous for great rejoicings and diversions of various sorts. The Galli carried the image of the goddess along the city, with the sound of drums and other music, in imitation of the noise which

Megara. ‖ Mehwas.

they made to prevent Saturn from hearing the cries of his infant son Jupiter, when he was disposed to devour him.

MEGARA, in *Ancient Geography*, a noble city, the capital of the territory of Megaris, which for many years carried on war with the Corinthians and Athenians. It had for some time a school of philosophers, called the *Megarici*, who were successors of Euclid the Socratic, a native of Megara. Their dialect was the Doric. Megara was situated at a distance from the sea, and about midway between Athens and Corinth. Its port was called *Nisæa*, from Nisus, son of Pandion the second, who obtained Megaris as his portion, when the kingdom of Athens was divided into four lots by his father. He founded the town, which was eighteen stadia or two miles and a quarter from the city, but united with it, as the Piræus was with Athens, by means of long walls.

MEGARIS, in *Ancient Geography*, the country of the Megarians, is described as a rugged region, like Attica; the mountain called *Oneian* or Asinine, now *Macriplayi* or the long mountain, extending through it towards Bœotia and Mount Cithæron. It belonged to Ionia or Attica, until it was taken by the Peloponnesians in the reign of Codrus, when a colony of Dorians settled in it. This territory had Attica to the east, Bœotia to the north and west, and the isthmus of Corinth to the south.

MEGASTHENES, a Greek historian, who flourished in the age of Seleucus Nicanor, about 300 years before Christ. He wrote concerning the oriental nations, particularly the Indians, and his history is often quoted by the ancients; but what now passes as his composition is spurious.

MEGIDDO, in *Ancient Geography*, a town of Galilee, enumerated amongst the cities of Manasseh, in the tribe of Issachar or Asser, on the western side of Jordan, and famous for the defeat of Ahaziah and Josiah, who perished there. (2 Kings xxiii. 29.)

MEGNA. This river is formed by the numerous streams which issue from the mountains that form the northern boundary of Bengal, of which the principal is the Brahmaputra, which joins it about lat. 24. 10., after which its size is greatly increased, and it assumes the name of the Megna. Below the city of Dacca it is joined by the Issamuthy, bringing the collected waters of the Dullasery, Boorigmega, Luckia, and many other smaller rivers, forming an expanse of water resembling an inland sea. From hence it approaches the sea by a SSE. course, when its volume is augmented by the Ganges, and the whole collected stream is rolled into the bay of Bengal. The muddy tide leaves a great quantity of sediment, which forms many islands, amongst which are Dukkinshabazpoor, thirty miles long and twelve broad, Hatha, Sundeep, and Bamony. Between these islands the tide rushes with great impetuosity, forming in spring tides what is called the Bore, which in a few minutes rises twelve feet in height. The sand-banks run nearly thirty miles into the sea, and will probably be one day habitable islands, like Sangor.

MEGO, or Pulo Mego isle, a small and uninhabited island, situated off the western coast of Sumatra. Like all the other low islands which lie off the western coast of Sumatra, it is so thickly skirted near the sea-beach with cocoa nut trees that their branches touch each other. Long. 101. S.E. Lat. 4. S.

MEHINDRY, a river of Hindustan, in the province of Gujerat, having a winding course of 190 miles. After passing the city of Ahmedabad, it falls into the Gulf of Cambay.

MEHWAS, a district of Hindustan, in the province of Gujerat, situated on the south-east bank of the Puddur river. It literally signifies the residence of thieves, which character attaches to the inhabitants, who live by plundering their neighbours. Every man who in this turbulent region can muster twenty horsemen, considers himself as an independent chief, and sets out on a marauding expedition.

Meibomiu

MEIBOMIUS is the name of several learned men, by birth Germans, who in their day enjoyed considerable reputation.

Meibomius, *John Henry*, was born in 1590 at Helmstadt, where he afterwards professed physic, and died at Lubeck in 1655, having been, for some time, first physician at that place. He was the author of several learned works on medical subjects, particularly, 1. *Jusjurandum Hippocratis*, Greek and Latin, 1643, in 4to.; and, 2. *De Usu Flagrorum in Re Medica*, Leyden, 1639. In the literary world he is known by a work, entitled *Mæcenas, sive de C. Cilnii Mæcenatis Vita, Moribus, et Rebus gestis*, Leyden, 1653, in 4to.; in which he has quoted almost every passage in the ancient authors where any thing is said of or allusion is made to Mæcenas, but has employed neither method nor criticism, and hence cannot lay claim to any higher merit than that of a mere collector.

Meibomius, *Henry*, son of the preceding, was born at Lubeck in 1638. After acquiring the elements of literature in his native place, he went, in 1655, to the university of Helmstadt, where he applied himself to philosophy and medicine, and afterwards studied at Groningen, Franeker, and Leyden. On his return to Germany, he undertook a tour through Italy, France, and England; contracted an acquaintance with the learned wherever he went; and took his degree in physic as he passed through Angers, in 1663. In 1664, he obtained a professorship of physic at Helmstadt, to which, in 1678, were joined the professorships of history and poetry, which he held until the time of his death, in March 1700. Besides a number of works relating to his own profession, he published *Scriptores Rerum Germanicarum*, 1688, in three vols. folio; an useful collection which had been commenced but not completed by his father.

Meibomius, *Marcus*, a learned man of the same family as the two preceding, was born in 1611. He early devoted himself to literature and criticism, particularly the learning of the ancients, and became eminently skilled in archæology. In 1652 he published a collection of seven Greek authors, who had written upon music, to which he added a Latin version by himself. It was entitled *Antiquæ Musicæ Auctores Septem Græce et Latine, Marcus Meibomius restituit et notis explicavit*, and forms the most celebrated of all his critical works. From these commentaries on the Greek musical writers, particularly Alypius, we can almost decipher the characters used by the Greeks in their musical notation; characters which, before the time of Meibomius, had been so altered, corrupted, and disfigured, by the ignorance or negligence of the transcribers of ancient manuscripts, that they had become nearly, if not altogether, unintelligible. The Queen of Sweden, to whom this publication was dedicated, invited Meibomius to her court; but his stay there was abridged by an occurrence equally ridiculous and extraordinary. He became the victim of one of those malicious tricks called practical jokes. The queen having imbibed somewhat of his enthusiasm in favour of the music of the ancients, was easily persuaded by Bourdelot, a physician in attendance on her person, to desire Meibomius to sing an ancient Grecian air, whilst an old Frenchman, named Naudet, should dance *à la Grec* to the sound of his voice. Meibomius of course complied with the royal request; but the performance, instead of exciting admiration, produced loud bursts of laughter, in which her majesty heartily joined. Meibomius, enraged beyond measure at this reception, chanced to espy Bourdelot in the gallery amongst the scoffers, and having no doubt that it was he who had maliciously instigated the queen to desire this performance, immediately flew thither, and unrestrained by the presence of her majesty, floored the luckless physician by a terrible facer, delivered with all the energy of passion. In consequence of this summary proceeding, the expounder of ancient music found it necessary to quit Sweden without the ceremony of asking leave, or waiting to be called to account

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for his conduct. He went to Copenhagen, where he was well received, and soon afterwards appointed professor in a college instituted for the instruction of the young Danish nobility. He was also honoured with the title of aulic counsellor, and advanced to the dignity of president of the board of maritime customs at Elsinore; but having neglected his duty, he was dismissed from his office, and obliged to quit Denmark in disgrace. He then proceeded to Amsterdam, where he settled, and became professor of history in the college of that place. But his evil fortune still pursued him; for having refused to give instructions to the son of a burgomaster, upon the ground that he was not accustomed to teach boys the elements of knowledge, but to direct the studies of young men advanced in learning, he was deprived of his situation, and forced to quit Amsterdam. Being again thrown upon the world, he visited France and England; after which he returned to Holland, where he led a private and studious life until 1711, when he died, at a very advanced age, having nearly completed a century. Meibomius pretended that the Hebrew Bible was full of errors, and undertook to correct them by means of a metre which he fancied he had discovered in the books of the Old Testament. But the whole scheme was an illusion, and drew upon the author the unsparing ridicule of the learned. Nevertheless, he was a scholar of no mean order, as is proved by his edition of Diogenes Laertius, Amsterdam, 1692, in two vols. 4to.; his *Liber de Fabrica Triremium*, 1671, in which he endeavours to explain how the ancients disposed their bancs of oars; his edition of the ancient Greek Mythologists; and his *Dialogues on Proportions*, in which Euclid, Archimedes, Appollonius, Pappus, Eutocius, Theon, and Hermotinus are the interlocutors. (A.)

MEINUNGEN, a city of Germany, the capital of the dominions of the Duke of Saxe-Meinungen. It stands on the river Werra, 830 feet above the level of the sea. It is a well built city, surrounded with walls and ditches, and having broad streets well paved. The principal building is the magnificent palace of the sovereign, whose front is 500 feet in length, exclusive of two wings, and has a good library and several valuable collections of minerals, coins, pictures, and natural history. It contains about 4200 inhabitants, who carry on some small manufactures, but subsist chiefly on the court and public offices. Lat. 50. 33. 53. N. Long. 10. 19. 1. E.

MEISENHEIM, a city of the landgravate of Hesse-Homburg, in Germany, the capital of the barony of that name, and containing 1227 inhabitants. The city is situated on the river Elan, is walled, and is the seat of the courts of law of the small state. It contains 420 houses and 1850 inhabitants, employed in making glass and iron, and in working a mine of quicksilver near to the town.

MEISSEN, one of the circles into which the kingdom of Saxony is divided, being formed out of the ancient margravate of that name. It extends over 1610 square miles, comprehends thirty-nine cities and towns, 1156 villages, and 309,460 inhabitants. It is divided into twelve bailiwicks, one of which bears the same name. It is a productive territory, but suffered much during the late war, from the effects of which it has scarcely yet recovered. The city of Meissen, which is the capital of the circle, is situated on the river Elbe, over which is a bridge in a picturesque situation, rendered more so from the Albertsburg, the ancient palace of the Saxon house, but now used for the manufacture of the celebrated china which has been commonly called Dresden. This fabric employs about 500 workmen, but is said to be attended with an annual loss to the king, who is the proprietor. Meissen contains in the town and suburbs 556 houses, with 4270 inhabitants, some of whom are employed in making linen and woollen goods, and in tanneries.

MEKRAN, a large maritime province of Persia, (the ancient Gedronia) which extends along the Indian ocean from Cape Jask to the borders of Scind, which bounds it on the east; on the west and north-west it is bounded by Kerman; and on the north by Seistan and Arakaje. It is a country which has been but little travelled by Europeans; but from the account of Captain Grant, who traversed the western part of this province in 1809, from Guattur to Cape Jask, it appears that the middle parts are entirely mountainous, diversified with valleys and plains, none of which is exceedingly fertile, whilst others are arid. The mountains run parallel with the coast, seldom at a greater distance than eight or ten miles excepting at Cape Jask and Chobar, where they approach almost the edge of the sea. The greatest elevation of this chain is at Surku, where the streams that rise on the south side flow towards the Indian ocean, and these which have their source on the south side to the Persian Gulf. Between the sea and the hills there is a level plain, seldom more than eight or ten miles in breadth, where is produced abundance of pasturage, and where Captain Grant observed numerous flocks of sheep and camels, often in droves of two or three hundred, and only once in his journey experienced a scarcity of water. The produce of the province consists of rice, dates, wheat, barley, jouree and cotton. They have two harvests; that of dry grain is in the end of March, and that of rice in September. Oxen are used in agriculture; and the horses are more remarkable for their hardiness and beauty. The towns and villages, most of which are surrounded with a few palm trees, consist of moveable mud huts, defended by a mud fort. The population of Mekran consists of many different tribes and independent chiefs; of these the Balooches are the most numerous. They are a middle-sized race of men, spare, muscular, and active; some live in towns, others in tents of black hair, migrating with their flocks from place to place. The women, unlike those in most Mussulman countries, are allowed to appear freely in public. The whole force in the country may amount to 25,000 men.

Mekka.

MEKKA, or MECCA, a large city of Arabia, and capital of the province of the Hedjaz, one of the holy cities of the Mahommedans, and the annual retreat of innumerable pilgrims, celebrated all over the east as the birth place of Mahommed, and the first seat of his power. It is situated in a narrow and sandy valley, the main direction of which is from north to south; the valley is from one to seven hundred paces in breadth, and the chief part of the city is situated where the valley is broadest. The town itself covers a space of about 1500 paces in length, from the quarter called El Shebeyka, to the extremity of the Mala. But the whole extent of ground comprehended under the denomination of Mekka, from the suburb called Djeronel, where is the entrance from Djidda to the suburb called Moabede on the Tayf road, is 3500 paces. The valley in which the city is built is enclosed by mountains from 200 to 500 feet in height, and entirely barren and destitute of trees. The town is partly built on the sides of the mountains, principally of the eastern chain, where the primitive habitations of the Koreysh and the ancient town appear to have been placed. The city was formerly protected by three walls at its extremities, but they are now decayed and it is open on every side; though the neighbouring mountains form a barrier of considerable strength against an enemy. Mekka may be styled a handsome town; its streets are in general broader than those of eastern cities, which seldom allow a greater space than is required for two camels to pass. But the numerous visitors who are crowded together in this holy city during the pilgrimage render it necessary to leave ample space in the streets. The houses are lofty, many of them being three stories in height, and they are built of stone; and the numerous windows that command a view of the streets give them a more lively and European aspect than the houses in most of the eastern towns, which present but few windows towards the exterior. Few of the houses are white-washed as at Djidda, being of a dark-coloured stone which

Mekka. is much preferable to a glaring white. Every house has its terrace, the floor of which, composed of a preparation of lime-stone, is built so as to allow the rain-water to run off through gutters into the street. These terraces are concealed from the view by slight parapet walls, as it is reckoned discreditable in the east that a man should appear upon the terrace, whence he might be accused of looking at women on the terraces of neighbouring houses, where they pass much of their time in various domestic duties, such as drying corn, hanging up linen, &c. Almost all the houses, except those belonging to the principal and richest inhabitants, are constructed for the accommodation of lodgers, being divided into many apartments, separated from each other, and each consisting of a sitting room and a small kitchen. The only public place in the body of the town is the ample square of the great mosque. No trees or gardens are interspersed amongst the houses to cheer the eye; but the scene is enlivened during the pilgrimage by the great number of well-stored shops which are found in every quarter. Mekka is more deficient in public buildings than any other eastern city of the same size; having nothing of this description excepting four or five large houses belonging to the scherif or governor, two colleges, now converted into corn magazines, and the mosque with some buildings and schools attached to it. Neither khans for the accommodation of travellers or for the deposit of merchandise, nor palaces of grandees, nor mosques, which adorn every quarter of other towns in the east, are here to be seen. This want of public edifices Burckhardt the enterprising traveller, to whose work we are indebted for this account of the holy city, ascribes to the veneration which the inhabitants entertain for their temple, to which they are averse to construct any rival edifice. The streets are all unpaved, in consequence of which the sand and dust are blown about in summer to the great inconvenience of the passengers; and so deep is the mud during the rainy season that they are scarcely passable after a shower, as the water stagnates in the interior of the town until it is dried up. It may also be ascribed to the destructive rains, which, though of shorter duration than in tropical countries, fall with violence, that no ancient buildings are found in Mekka. Burckhardt is of opinion that there are not any houses more than four centuries old; and hence there are here no interesting specimens of architecture or any such beautiful remains of Saracenic structures as are still admired in Syria, Egypt, Barbary, and Spain. No regulations of police are enforced in Mekka as in other eastern cities. The streets are totally dark at night, no lamps of any kind being lighted; and its different quarters are without gates, differing in this respect also from most eastern towns, where each quarter is regularly shut up after evening prayers. The dirt and sweepings of the houses are cast into the streets, where they add to the accumulated mass of dust or mud according to the season. Another great inconvenience, and one great cause of dirtiness and also of disease, is the scarcity of water, which is here fully as much felt as at Djidda. There are but few cisterns for collecting rain, and the well water is so brackish that it is used only for culinary purposes, except during the time of the pilgrimage, when the lowest class of the pilgrims drink it. The famous well of Zemzem in the great mosque is indeed sufficiently copious to supply the whole town, but its water is heavy to the taste and impedes digestion. The best water in Mekka is brought from a conduit in the vicinity of Arafat, about thirty miles distant. This conduit is wholly built of stone, but it is greatly neglected and has fallen into decay, so that most of the water is lost in its passage to the city through apertures, or slowly forces its way through the obstructing sediment; and hence the supply is barely sufficient in ordinary times for the use of the inhabitants, and during the pilgrimage sweet water is so scarce that a small skin of it is often sold for the value of a shilling, a very high price amongst the Arabs. At two places the aqueduct runs above ground, and there the water is let off into small channels and fountains, at which a toll is exacted by the slaves of the scherif for liberty to fill the water-skins; and here during the pilgrimage crowds are to be seen day and night quarelling and fighting for access to the water. When the Wahabees besieged the place they cut off this supply of water, and it was not till some time afterwards that the injury was partially repaired. There is a small spring which oozes from under the rocks behind the great palace of the scherif which affords excellent water, but it is wholly appropriated to the use of the scherif's family. It has been already mentioned that there are few public buildings of any consequence in Mekka. The castle stands nearly on the summit of the range of mountains which enclose the town; it commands the greatest part of the city, but is itself commanded by several higher summits. The building was considerably strengthened and repaired by Ghaleb, a scherif of Mekka, who mounted it with heavy guns. It contains a large cistern and a small mosque, and might accommodate a garrison of 1000 men. It is an impregnable fortress against the attacks of Arabs, and might even offer some resistance to Europeans. The approach is by a steep and narrow path. Below the castle hill upon a small plain stands the great palace of the reigning scherif; it has high and solid walls and seems to have been intended for an out-work to the castle above it, with which, according to the reports of the Mekkawy, there is a subterranean communication. It is an irregular pile of building and comprises many spacious courts and gloomy chambers; it is now converted into a magazine of corn. The most remarkable building in Mekka is the mosque, called the Beitullah, which, however, is only remarkable on account of the Kaaba which it encloses; there being several mosques in other places of the East nearly equal to it in size, and much superior in beauty. The Kaaba is contained in an oblong square 250 paces in length, and 200 in breadth; this open square is enclosed by a quadruple row of pillars, some of white marble, granite, or porphery, but the greater part of the common stone of the Mekka mountains; these pillars are united by pointed arches, every four of which support a small dome; from the arches lamps are suspended, some of which burn every night, and the whole are regularly lighted up during the nights of Ramadan. The Kaaba is an oblong massive structure of the grey Mekka stone, eighteen paces in length, fourteen in breadth, and from thirty-five to forty feet in height; seven paved colonnades, of sufficient breadth to admit four or five persons to walk abreast, lead towards the Kaaba in the centre. At the south-east corner of the Kaaba, near the door, is the famous "black stone," said to have been brought by the angel Gabriel to form the foundation of the edifice. It forms a sharp angle of the building, at four or five feet from the ground. It is an irregular oval, about seven inches in diameter, consisting of a dozen smaller stones cemented, and perfectly smoothed by the millions of touches and kisses which it has received. The grand ceremony through which the pilgrims pass, is to go seven times round the Kaaba, reciting certain appointed verses and prayers, and kissing the sacred stone. In the south-east corner of the Kaaba is another stone which the people, walking round the Kaaba, touch only with the right hand. On the north side there is a hollow in the ground lined with marble; and here it is thought meritorious to pray. The four sides of the Kaaba are covered with a black silk stuff, hanging down and leaving the roof bare. Round the Kaaba there is a good pavement of marble, and opposite the four sides stand four other buildings, where the Imaums of the orthodox Mahommedan sects take their station and guide the congregation in their prayers. The building which encloses the Zemzem, or well of holy water, of which the pilgrims take large draughts, and which Mekka.

Mela.

is supposed to cure all diseases, (besides a thorough ablution in its waters, which, they imagine, purifies from sin), is of a square form with an entrance into the room which contains the well, and which is ornamented with marbles of various colours. Adjoining there is a small stone reservoir which is always full of Zemzem water. This room is constantly filled with visitors from dawn till near midnight. The outside walls of the mosque are those of the houses which surround it on all sides. These houses belonged originally to the mosque, and they are let out as lodgings to the richest hadjis at high prices. The mosque has nineteen gates, and its interior is adorned with seven minarets irregularly distributed. It will be seen that the general plan of the mosque, from the above account, differs but little in its construction from the mosque of Zakania at Aleppo, the large mosque called El Amvay at Damascus, and the greater number of the mosques at Cairo, which are constructed exactly upon the same plan, with an arched colonnade round an open square. For further particulars respecting the ancient and celebrated structure, the reader is referred to Burckhardt's work on Arabia, which contains ample and interesting details on this subject.

The population of Mekka may all be styled foreigners, or the offspring of foreigners, except a few Hedjaz Bedouins, or their descendants who have settled here. The most numerous are those whose fathers came from Yemen and Hadramaut; and next to them in numbers are the descendants of Indians, Egyptians, Syrians, Mogrebyns and Turks. There are also Mekkawys of Persian origin, Tartars, Bokhars, Kurds, Afghans; and, in short, inhabitants from every Mahommedan country in the world. They have but two kinds of employment; trade and the service of the Beitullah or Temple. They are extremely commercial in their habits, and almost all the olemas, or persons engaged in the service of the temple, are secretly engaged in trade. With the exception of a few poteries and dyeing houses, Mekka has not a single manufactory, but during the time of the pilgrimage it is the seat of a very extensive trade; the wealthy pilgrims bringing from every Mussulman country its native productions to Djidda, either by sea or across the desert from Damascus, and exchanging them amongst each other, or receiving from the merchants of Mekka the goods of India and Arabia which the latter have accumulated the whole year in their warehouses. Mekka at this time becomes one of the largest fairs in the East, and is interesting from the variety of natives who frequent it. Whilst there is peace with the interior a considerable trade is carried on with the Bedouins, and especially with the inhabitants of the towns of Nedjed, who are in want of India goods, rings, and articles of dress, which they procure either from Medina or at a cheaper rate from Mekka. The rise of the Wahabee power in Arabia was rather unfavourable to Mekka. The pilgrims who visited the holy city were afraid to send their goods lest they should be seized by the Wahabees, and the imports were reduced to what were necessary for the inhabitants. Burckhardt, from all the inquiries he could make, estimated the stationary inhabitants at between 25,000 and 30,000, besides from 3000 to 4000 Abyssinian and black slaves. The climate is sultry and unwholesome; the heat is reflected from the rocks which enclose the narrow valley, and suffocating hot winds occasionally prevail. Inflammatory fevers and dysentery are common and often fatal. Mekka surrendered to the Wahabees in 1803, but was retaken by Ali Pasha's troop under his son Toussoun Bey in 1813. Long. 40. 15. E.; Lat. 21. 18. 9. N.

MELA, Pomponius, the earliest Roman geographer, whose work has been preserved, lived, most probably in the reign of Claudius, A. D. 43, though we have no precise information respecting him. The passage which seems to place him in the time of Claudius, is that (iii. 6.) where he speaks of a mighty emperor who is going to celebrate a triumph on account of the conquest of Britain, and this conquest we know took place A. D. 42. Julius Cæsar only reconnoitered the coast and could not be said to have subdued the island. Mela (ii. 6.) names the place of his birth, but the different manuscripts give various readings. It was certainly in Spain but whether it was Tingentera or Cingentera, and in what part of the country it was situated, we do not know. His name is also written Mella in many of the ancient manuscripts. The family too from which he was descended is equally a subject of dispute. Some imagine that he was descended from the family of Annæus, and suppose either that he was the son of Marcus Annæus Seneca, the orator, or that he was his grandson by L. Annæus Seneca, the celebrated philosopher. The former opinion is grounded principally on the fact that Seneca the orator has dedicated the first and the fifth of his ten books to his three sons, M. A. Novatus, L. A. Seneca, and L. A. Mela. The chief objections arise from our never finding Annæus preceding the name of Mela. The work of Mela on geography is entitled *De situ Orbis*, in three books, and has come down to us in the same state as Mela wrote it, with the exception of the numerous blunders of the transcribers. He has derived most of his information from Greek geographers, adopting, more particularly, the system of Eratosthenes. After a few introductory remarks on the globe in general, the author in his first book gives a description of Mauritania on the western coast of Africa, then Numidia, Africa Proper, Egypt, Arabia, Syria, Cilicia, Pamphylia, Lycia, Caria, Ionia, Æolis, Bithynia, Paphlagonia, and the other districts along the coast of the Euxine. In his second he describes the countries on the banks of the Tanais, *(Don)*, the Scythians, Thrace, Macedonia, Thessaly, Hellas, Peloponnesus, Epirus, Illyria, Gaul, Spain, and terminates his description where he began. In the third he describes the north-western coast of Spain, Germany, Sarmatia, the countries on the Caspian sea, Carmania, Persia, Arabia; then he passes into Africa, where he gives some account of western Ethiopia, and terminates his description at Cape Ampelusia, in Mauritania. The style of Mela is concise and spirited, though somewhat affected. The best editions are those of Gronovius, 1696, and of Tzschucke, Leipzig, 1806. (See Tzschucke *Diss. de Pomponio Mela.*)

Melah ‖ Melampus.

MELAH, a town of Hindustan, in the Rajpoot territories, and province of Ajmeer, forty-eight miles SSE. from Zandpoor. Long. 73. 33. E. Lat. 25. 49. N.

MELAMPUS, in fabulous history, a celebrated soothsayer and physician of Argos, the son of Amythæon and Idomenea or Dorippe, who lived at Pylos in Peloponnessus. His servants once killed two large serpents which they found at the bottom of a large oak; and Melampus paid so much regard to their remains, that he raised a pile, upon which he burned them. He also took particular care of their young ones, and fed them with milk. Some time after this the young serpents crept to Melampus as he slept on the grass near the oak, and, as if sensible of the favours of their benefactor, they wantonly played around him, softly licking his ears. This awoke Melampus, who was astonished at the sudden change which his senses had undergone, finding himself acquainted with the chirping of the birds, and with all their rude notes, as they flew around him. Taking advantage of this supernatural gift, he made himself perfect in the knowledge of futurity, and Apollo also instructed him in the art of medicine. He had soon afterwards the happiness of curing the daughters of Prœtus, by giving them hellebore, which from that circumstance has been called *melampodium;* and as a reward for his skill, he received the eldest of these princesses in marriage. The tyranny of his uncle Neleus, king of Pylos, obliged him to leave his native country; and Prœtus, to shew himself more sensible of his services, gave him part of his kingdom. About this time the personal charms of Pero, the daughter of Neleus, had

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gained many admirers; but the father promised his daughter to him only who should bring into his hands the oxen of Iphiclus. This condition displeased many; but Bias, who was also one of her admirers, engaged his brother Melampus to steal the oxen and deliver them to him. Melampus was caught in the attempt, imprisoned, and nothing but his services as a soothsayer and physician to Iphiclus could have saved him from death. All this pleaded in the favour of Melampus; but when he had taught the childless Iphiclus how to become a father, he not only obtained his liberty, but also the oxen, and, besides, he compelled Neleus to give Pero in marriage to Bias. A severe distemper, which had rendered the women of Argos insane, was totally removed by Melampus; and Anaxagoras, who then sat on the throne, rewarded his merit by giving him part of his kingdom, where he established himself, and where his posterity reigned during six successive generations. He received divine honours after death, and temples were erected to his memory.

MELANCTHON (Schwartzerd), Philip, born at Bretten in the Palatinate, in 1495, was one of the wisest and most able men amongst the reformers, though of a mild temper, and disposed to accommodate rather than to inflame disputes. In his youth he made great progress in learning, and was appointed professor of Greek at Wittenberg in 1509. Here his lectures upon Homer and the Greek text of St. Paul's epistle to Titus, drew to him a great number of auditors, and entirely effaced the contempt to which his low stature and mean appearance had exposed him. Melancthon reduced the sciences to system, and acquired such reputation, that he had sometimes between two and three thousand auditors. He soon formed an intimate friendship with Luther, who taught divinity in the same university; and in 1519 they went together to Leipzig, to dispute with Eccius. The following years he was continually engaged in various employments; he composed several books; he taught divinity; he performed several journeys, in order to found colleges and visit churches; and in 1530 he drew up a confession of faith, which goes by the name of the *Confession of Augsburg*, because it was presented to the emperor at the diet held in that city. All Europe felt convinced that he was not, like Luther, backward to accommodate the differences between the various sects of Christians. He hated religious disputes, into which he was drawn only from necessity by the part which he was called to act in the world; and he would therefore have sacrificed many things to produce an union amongst the Protestants. For this reason, Francis I. wrote to desire him to come and confer with the doctors of the Sorbonne, in order to agree with them about putting an end to all controversies; but although Luther endeavoured to persuade the Elector of Saxony to consent to that journey, and though Melancthon himself desired it, that prince, whether distrusting Melancthon's moderation, or afraid of quarrelling with the Emperor Charles V., refused to grant his permission. The king of England, Henry VIII., also desired to see him, but in vain. In 1529 Melancthon assisted at the conferences of Spires; and in 1541 he was present at the famous conferences at Ratisbon. In 1543 he went to meet the archbishop of Cologne, to assist him in introducing the reformation into his diocese; but that project came to nothing. In 1548 he assisted at seven conferences on the subject of the *Interim* of Charles V., and wrote a censure on that *Interim*, and all the writings presented at these conferences. He was extremely affected at the dissensions excited by Flaccus Illyricus. His last conference with those of the Roman Catholic communion took place at Worms, in 1557. He died at Wittenberg in the year 1560, and was interred near Luther. Some days before his death, he wrote upon a piece of paper the reasons which induced him to look upon death as a happiness; the chief of which was, that it would deliver him from theological persecutions. Nature had given Melancthon a peaceable and moderate temper, which was but ill suited to the time in which he lived. His moderation served only to increase his troubles. He was like a lamb in the midst of wolves. Nobody liked his mildness; it appeared as if he was lukewarm; and even Luther himself was sometimes exasperated against him. Melancthon was a man in whom many good as well as great qualities were united. He had parts and learning, sweetness of temper, moderation, contentedness, and other virtues, which would have made him happy in any times but those in which he lived. He never affected dignities, or honours, or riches, but was rather negligent of all these things, indeed, too much so in the opinion of some, considering he had a family; and his son-in-law Sabinus, who possessed a more ambitious temper, was actually at variance with him upon this very account. Learning was on many accounts infinitely obliged to him; but on none more than this, that, as already observed, he reduced almost all the sciences which had been previously taught in a vague irregular manner into system. Considering the distractions of his life, and the infinity of disputes and tumults in which he was engaged, it is astonishing how he found leisure to write so many books. Their number was so great, that it was thought necessary to publish a chronological catalogue of them in the year 1582. His works indeed are not correct, and he himself owned it; but as he found them useful, he chose rather to print a great number, than to finish only a few, "which, however," as Bayle observes, "was postponing his own glory to the advantage of others." His constitution was very weak, and required great tenderness and management; a circumstance which made Luther, fiery and zealous as he was, blame him for labouring too earnestly in the vineyard.

Melanippides. || Melchisedec.

MELANIPPIDES, in fabulous history, a Greek poet who flourished about 520 years before Christ. His grandson, of the same name, flourished about sixty years thereafter at the court of Perdiccas of Macedonia. Some fragments of their poetry are still extant.

MELAPO, a town of Anatolia, the ancient Mylasa, formerly adorned with magnificent temples. It is still a large town, situated in a fertile plain, but the houses are mean. It is eighty miles south of Smyrna.

MELCHITES, in church history, the name given to the Syriac, Egyptian, and other Christians of the Levant. The Melchites, excepting some few points of little or no importance, which relate only to ceremonies and ecclesiastical discipline, are in every respect professed members of the Greek church; but they are governed by a particular patriarch, who resides at Damascus, and assumes the title of Patriarch of Antioch. They celebrate mass in the Arabian language. The religious amongst the Melchites follow the rule of St. Basil, which is common to all the Greek monks. They have four fine convents distant about a day's journey from Damascus, and never quit the cloister.

MELCHISEDEC, (מלכי־צדק, *rex justitiæ*), the name of an individual who occupies an important place amongst the characters which appear in the Old Testament history, as typical of Christ. Very little, however, is said in Scripture regarding him personally; his name occurs only twice in the Old Testament, (in Gen. xiv. 18, and in Ps. cx. 4); and the reference to him in the New, (in Heb. vii. 20. and vii. 1.), has respect only to his typical character. His name is mentioned for the first time in the sacred history, on the occasion of the return of Abraham from the defeat of the four kings or sheikhs who had invaded the district of Sodom, and carried captive his nephew Lot. In the valley of Shaveh, or "the king's dale," probably the same valley as that mentioned under the same name in 2 Samuel (xviii. 18), the victor was met by Melchisedec, who is described as "the king of Salem," and who, with the generous readiness of

Melchisedec.

eastern hospitality, set before him and his troop "bread and wine," that is, a plentiful repast.[1] The Salem here mentioned is not to be confounded with the Salem spoken of in Psalm lxxvi. 2, where it is plainly Jerusalem that is referred to, but must have been some city, unknown to general history, which lay somewhere between Damascus and Sodom, to which district the narrative of Moses fixes the route of Abraham's march.[2] In addition to his royal dignity he sustained also the sacerdotal office: "he was priest of the most high God;" and in this capacity he pronounced a benediction on Abraham. In return for his kindness, and especially from reverence to his priestly office, the patriarch gave him a tithe of all the spoil he had taken in that expedition, from which he was then returning.

This is the sum of what Moses records respecting Melchisedec; and the only addition that can be made to the recital from the other passages above referred to is, that his priesthood was not derived from hereditary descent, but had been conferred on him by the immediate appointment of God.[3] Meagre, however, as this account is, there is something in the character and position of the individual to whom it refers of so singular a nature, as at once to excite curiosity and stimulate further investigation. That in a land inhabited by the accursed race of Canaan, and at a time when the knowledge of the true God was confined apparently to Abraham and his dependents,[4] an individual descended from that race should have been found, uniting in himself the two offices of priest and king, worshipping the true God of heaven and of earth,[5] and so eminent in dignity and piety, that his blessing was gratefully received by Abraham, and the divinity of his priesthood acknowledged on the part of the patriarch, by an offering to him of tithes, is a circumstance which cannot fail to excite the surprise of every reader of the sacred narrative. It is natural for him to ask, Who or what was this extraordinary character? From what race did he spring? Whence did he derive his knowledge of the true God? Or how came he to be "a king of righteousness," and "a king of peace," as well as a priest of God, in the land of Canaan? To these questions the narrative of Moses furnishes no reply, and what is said of him in other parts of Scripture[6] only tends to heighten our curiosity, by the elevated rank which is there assigned to him, as a type of the Messiah. Our only resource in such a case is probable conjecture, and to this it is not surprising that expositors of the Scriptures, both in ancient and modern times, should have had recourse; nor is it to be wondered at that the opinions which they have advocated on the subject have been both numerous and discordant. To recapitulate the whole of these would only be to occupy space which might be far more usefully filled; we shall, therefore, confine ourselves to a statement of one or two of the most prominent, with a brief view of the arguments by which they have been enforced.

1. By the Jewish expositors generally, Melchisedec is said to have been Shem, the son of Noah, and this, as we learn from Epiphanius, (*Haeres.* lv. p. 205), was also the opinion entertained by the Samaritans. It has likewise been held by a few Christian interpreters, amongst whom is Luther. The passages from Jewish writers advocating it, have been carefully collected by Bochart, (*Phaleg.* lib. ii. c. 1), who has also very satisfactorily shewn its absurdity; apart from the decisive evidence furnished against it by the statement of Paul, that Melchisedec was one whose descent could not be identified with that of the Levites, (μὴ γενεαλογούμενος ἐξ ἀυτων, Heb. vii. 5), a statement which is not true of Shem, who was in the regular line of Levi's progenitors. It seems highly unreasonable that Moses, who often mentions Shem, should here introduce him under another name, without giving any explanation as to the person really intended; nor is it easily conceivable that Abraham should have been described as "sojourning in a *strange* country," if he had been in the immediate vicinity of his ancestor Shem. The Jews, moreover, are not unanimous in this opinion, for Josephus tells us that Melchisedec was a prince of the Canaanites;[7] and in one place of the rabbinical book Sohar,[8] he is spoken of as a *type of the king of true peace.*

Melchisedec.

2. Augustin and Theodoret severally inform us of a class of heretics in the early church, who received the name of Melchisedechians, from their holding the opinion that Melchisedec was a mighty divine power, (*dei virtutem*, μεγάλην τινα καὶ θείαν δυνάμιν), superior to Christ, and the model after which Christ was formed. The founder of this sect was one Theodotus, an usurer, who seems to have flourished about the year 174.[9] An advance upon this opinion was made by Hierax, who, as we learn from Epiphanius, identified this divine power with the Holy Spirit. (*Haer.* lv. p. 304). The sect seems to have commanded little attention, and their opinion is worthy of notice only as forming one of the heresies of the early church.

3. By some of the fathers, and not a few of the more modern expositors, Melchisedec has been regarded as the Logos or second person of the Trinity, who appeared to Abraham, not incarnate, but only, as Epiphanius expresses it, ἐν ἰδέᾳ ἀνθρώπου, in the model of man. In defence of this opinion, its advocates adduce, 1st, the acknowledged fact that such appearances were vouchsafed to the patriarchs, as in the case of Abraham, when "the *Lord*" communed with him respecting the destruction of Sodom, and of Jacob, when he wrestled with the angel, and saw "*God* face to face;" 2dly, the evident mystery attached in Scripture to the person and character of Melchisedec, "of whom," says Paul, "we have many things to say and hard to be uttered;"[10] 3dly, the assertion of the same apostle that Melchisedec was not mortal, implied in his declaration, that whilst other men who receive tithes die, "it is witnessed of him that he liveth;"[11] 4thly, the strong and unqualified terms in which the unearthly origin of the "order" of his priesthood, and its perpetual duration, are spoken of by the same apostle, as well as by the psalmist;[12] 5thly, the language of Paul in regard to the mysterious existence of Melchisedec, as "without father, without mother, without descent, having neither beginning of days nor end of life," language strikingly applicable to Christ, "whose goings forth have been of old from everlasting," but hardly to be understood of a mere man; and, *finally*, the circumstance of Melchisedec's receiving tithes as a free-will offering from Abraham, an homage which was rendered by the pious to none but the Almighty. On the side of this theory are ranked some eminent names both in the early and in the modern church. It is enough to mention those of Ambrose, Damianus, Moulin, Cunæus, Outrein, Hottinger, Starke, Gaillard, Ridgley, Hunter, Henry, and Brown. A very able defence of this opinion has recently appeared in a work entitled, *Melchizedek*, by the author of Balaam, Elijah, &c. London, 1834, the production, we believe, of a lady.

4. By far the most common opinion is, that Melchisedec was a righteous and powerful king, a worshipper and priest

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[1] Patrick, *in loc.* Josephus, *Antiq.* i. 9.
[2] See this clearly shewn by Bochart, *Phaleg*, l. ii. c. 4.
[3] Heb. vii. 3. Fuller *on Gen.* xiv. 18.
[4] Josh. xxiv. 2.
[5] Gen. xiv. 19
[6] Ps. cx 4. Heb. vi. 20.
[7] Χαναναίων δυνάστης. *De bell. Jud.* vii. 18.
[8] Lech lecha, fol. 60, col. 237, ed. Sulz., quoted in Professor Tholuck's *Comment. zum briefe an d. Heb.* in loc.
[9] Theodoret, *Haer. fab.* lib. ii. cap. 6. ap. Suicer. *Thes. Eccl.*
[10] Heb. v. 11.
[11] Heb. vii. 8.
[12] Heb. vii. 3, &c. Ps. ex. 4.

Melcomb-Regis.

of the Most High God, in the land of Canaan, and a type of Jesus Christ. In support of this opinion it is contended, 1st, that the mysterious character attributed to Melchisedec in Scripture, is nothing more than belongs to all the prophetical types; and that when Paul says he has many things to say respecting him which are hard to be uttered, he only means that owing to the carnality of those to whom he was writing, the revelation which he was about to give of the *spiritual* character of Melchisedec as a type of Christ, would not be easily apprehended;[1] 2dly, that his being described as ἀπατωρ και ἀμήτωρ, implies nothing more than that his descent was not matter of record, in the same way as Sarah is called ἀμήτωρ by Philo, because her mother's name is not known, or as Servius Tullius is said by Livy to have been born *patre nullo, matre serva*, because only his mother's name (Cornicula) was matter of history; 3dly, that what is said of his being "without beginning of days or end of life," refers merely to our ignorance of the time and manner of his birth and of his death, which are purposely left unrecorded in order that he might serve as a type of Christ "who ever liveth;" 4thly, that in all the *certain* instances of divine appearances recorded in the Old Testament, the fact of the Deity's being present is made apparent in the narrative itself, and that this not being done in the case of Melchisedec renders it unjustifiable, without express authority from some other part of Scripture, to suppose that he was such an appearance; 5thly, that had Melchisedec been himself the Son of God, the apostle would not have said that he was "made like (*ἀφωμοιωμένος, assimilatus, likened to, compared to)* the Son of God," for this would have been to compare him with himself; 6thly, that no sufficient reason is apparent from the narrative for so extraordinary a revelation as that of the second person of the Trinity in human shape, nor does any end worthy of such means seem to have been answered by the interview; and, *finally*, that Abraham's offering of a tithe of the spoil might with great propriety be presented to Melchisedec though only a man, as an act of homage not to himself, but to that God whose priest he was and in whose name he had blessed the patriarch. This view of the subject has been adopted by a majority of the fathers as well as of modern divines. It has been strenuously defended by Dr. Owen in his work on the Hebrews, where he denounces the opposite opinion as a series of "groundless fables," and "woful mistakes," and has received the suffrages of the greater part of those who have commented upon that epistle, amongst whom may be mentioned the names of Calvin, Cameron, Scott, Blomfield, Stuart, Kuinoel, and Tholuck. It may be regarded as the *common* opinion of the orthodox church.

According to this opinion, the reasoning of St. Paul in the passage referred to goes to establish an analogy between Melchisedec and Christ, in respect of the following points: 1st, of *name* and *designation*, both being denominated "king of righteousness," and "king of peace;" 2dly, of *obscurity of descent*, both being without beginning of days or end of life, the one because his genealogy is not recorded, the other because with regard to him this was literally true; 3dly, of *the homage rendered to both by their receiving tithes as a free-will offering*, the one in the name of the God whom he served, the other in his own name; 4thly, *of the peculiar character of the office they sustained*, neither having had either predecessors or successors, the one, because God arranged it so, the other, because it was of necessity so; and, 5thly, *of the superiority of both to the priests under the law*, the one having blessed, as a superior, Abraham the father of Levi, the other having abolished the whole economy of the Levitical priesthood by the sacrifice of himself.[2]

MELCOMB-REGIS, a town of Dorsetshire, in the hundred of Culliford-tree, 127 miles from London. It is situated on the right bank of the river Wey, which divides it from Weymouth, both which towns are connected together by the bridge. The two towns have one corporation of mayor and aldermen between them, and formerly chose four members to parliament, each person entitled to the franchise having four votes. By the new law, an alteration has been made, and the towns united chuse two members only. The whole are commonly called Weymouth, though Melcomb is the larger place of the two, and that in which are the market, town hall, and custom house, and wherein are the best houses for the accommodation of the visitors who resort to it for the purpose of sea-bathing, for which the shore is peculiarly adapted. The market is held on Tuesday. The population was in 1801, 2350; in 1811, 2985; in 1821, 4252; and in 1831, 5126.

Meleager.

MELEAGER, in fabulous history, a celebrated hero, the son of Oeneus, king of Calydonia, by Althæa, daughter of Thestius. The Parcæ were present at the moment of his birth, and predicted his future greatness. Clotho said that he would be brave and courageous; Lachesis foretold his uncommon strength and valour; and Atropos declared that he should live as long as that firebrand, which was on the fire, remained entire and unconsumed. Althæa no sooner heard this, than she snatched the stick from the fire, and kept it with the most jealous care, as the life of her son totally depended upon its preservation. The fame of Meleager increased with his years. He signalized himself in the Argonautic expedition, and afterwards delivered his country from the neighbouring inhabitants, who made war against his father at the instigation of Diana, whose altars Oeneus had neglected. But Diana punished the negligence of Oeneus by a greater calamity. She sent a wild boar, which laid waste all the country, and seemed invincible on account of its immense size. It soon became a public concern; all the neighbouring princes assembled to destroy this terrible animal; and nothing is more famous in mythological history, than the hunting of the Calydonian boar. The princes and chiefs who assembled, were Meleager son of Oeneus, Idas and Lynceus sons of Apharcus, Dryas son of Mars, Castor and Pollux sons of Jupiter and Leda, Pirithous son of Ixion, Theseus son of Ægeus, Anceus and Cepheus sons of Lycurgus, Admetus son of Pheres, Jason of Æson, Peleus and Telamon sons of Æacus, Iphicles son of Amphitryon, Eurytrion son of Actor, Atalanta daughter of Schœneus, Iolas the friend of Hercules, the sons of Thestius, Amphiaraus son of Oileus, Protheus, Cometes, the brothers of Althæa, Hippothous son of Cercyon, Leucippus, Adrastus, Ceneus, Phileus, Echion, Lelex, Phœnix son of Amyntor, Panopeus, Hyleus, Hippasus, Nestor, Menœtius the father of Patroclus, Amphicides, Laërtes the father of Ulysses, and the four sons of Hippocoon. This troop of armed men attacked the boar, which was at last killed by Meleager. The conqueror gave the skin and the head to Atalanta, who had first wounded the animal. This irritated the rest, and particularly Toxeus and Plexippus the brothers of Althæa, and they endeavoured to rob Atalanta of the honourable present. Meleager defended her, and killed his uncles in the attempt. Meantime the news of this celebrated conquest had already reached Calydon, and Althæa went to the temple of the gods to return thanks for the victory which her son had gained; but being informed that her brothers had been killed by Meleager, she in a moment of resentment threw into the fire the fatal stick on which her son's life depended, and Meleager died as soon as it was consumed. As Homer does not mention the firebrand, and some have hence imagined that this fable is posterior to that poet's age. But he informs us, that the death of

[1] The word he uses is δυσερμήνευτος which the Vulgate renders *ininterpretabilis*.
[2] See Chrysostom *Homil.* Calvin *Comment.* Tholuck *Comment* in loco, &c. &c.

Meleager ‖ Melicerta.

Toxeus and Plexippus so irritated Althæa, that she uttered the most horrible curses and imprecations upon her son's head.

MELEAGER, a Greek poet, was the collector of the first Anthologia that is known. Neither the place where he was born, nor the time at which he flourished is known with any degree of precision. We think that Mr. Clinton (*Fasti Hellenici*, xi. p. 541) proves that he is not Meleager, the cynic of Gadara, the contemporary of Menippus, but that he flourished after Antipater Sidonius somewhere about 95 B.C. Meleager was the editor of a collection of fugitive pieces of poetry, and the author of some original poems. His collection was made from the works of forty-six authors, and was entitled Στεφανος, the Garland. The authors were Anytus, Myro, Sappho, Melanippides, Simonides, Nossis, Rhianus, Erinna, Alcæus, Samillo, Leonidas, Mnasalces, Pamphilus, Pancrates, Tymnes, Nicias, Euphemus, Damagetes, Callimachus, Euphorion, Hegisippus, Perseus, Diotimus, Menecrates, Nicænetes, Phaennus, Simmias, Parthenis, Bacchylides, Anacreon, Anthemius, Archilochus, Alexander Œtolus, Polycletus, Polystratus, Antipater, Posidippus, Hedyles, Sicelides, Plato, Aratus, Cheremon, Phedimus, Antagoras, Theodorides, and Phanias. This collection has disappeared, but we possess one hundred and thirty-one pieces which are said to have been the production of this poet. They are written principally on amorous subjects, and are remarkable for the elegance of their versification. The best editions of Meleager are that of Manso, (Iena 1789,) of Meinecke, (Lips. 1789,) and of Græfe (Lips. 1811.) See Fabricius, *Biblioth. Græca*, tom. iv.; *Prolegomena* to the *Anthologia Græca* of Jacobs; Reiske in his Preface to his *Anthologia Græca;* Schneider in his *Analecta Critica*, facic. 1.; Burette, *Mémoires de l'Acad. des inscript.* xix.

MELETIANS, in ecclesiastical history, the name of a considerable party who adhered to the cause of Meletius, bishop of Lycopolis, in Upper Egypt, after he had been deposed, about the year 306, by Peter bishop of Alexandria, on the charge of having sacrificed to the gods, and been guilty of other heinous crimes; though Epiphanius represents as his only failing an excessive severity against the lapsed. This which was at first a personal difference between Meletius and Peter, became a religious controversy; and the Meletian party subsisted in the fifth century, but was condemned by the first council of Nice.

MELFI, a city of the province Basilicata in the kingdom of Naples, being the seat of a Bishop, to whose see Napolla is united. It is situated on the river Antroluco, near its junction with the Ofanto, and contains, besides a cathedral, fourteen churches, eight monasteries, and 7400 inhabitants.

MELFORD-LONG, a town of the county of Suffolk, fifty-seven miles from London. It is situated on the river Stour, and consists of one street about a mile in length. The church is a beautiful gothic building. The country round is pleasant, and ornamented with several gentlemen's seats. The population in 1801 amounted to 2204; in 1811 to 2068; in 1821 to 2288; and in 1831 to 2514.

MELIBOEA, in *Ancient Geography*, an island of Syria, at the mouth of the Orontes, which before it falls into the sea, forms a spreading lake round it. This island was famous for its purple dye. It was believed to be a Thessalian colony; and hence Lucretius's epithet of *Thessalicus*.

MELICERTA, MELICERTES, or *Melicertus*, in fabulous history, a son of Athamas and Ino. He was saved by his mother from the fury of his father, who prepared to dash him against a wall as he had done his brother Learchus. The mother was so terrified that she threw herself into the sea with Melicerta in her arms; but Neptune took compassion on the misfortunes of Ino and her son, and changed them both into sea deities. Ino was called *Leucothoe* or *Matuta;* and Melicerta was known amongst the Greeks by the name of *Palæmon*, and amongst the Latins by that of *Portumnus*. Some suppose that the Isthmian games were instituted in honour of Melicerta.

Melinda ‖ Melksham.

MELINDA, a kingdom on the east coast of Africa, situated, according to some, between the third and fourth degree of south latitude; though there is great disagreement amongst geographers as to its extent. It is allowed by all, however, that the coasts are very dangerous; being full of rocks and shelves, and the sea at some seasons very liable to tempests. The kingdom of Melinda is for the most part rich and fertile; producing almost all the necessaries of life except wheat and rice, both which are brought thither from Cambaya and other parts; and those who cannot purchase them make use of potatoes in their stead, which are here fine, large, and plentiful. They likewise abound with great variety of fruit trees, roots, plants, and other esculents, and with melons of exquisite flavour. They have also great plenty of venison, game, oxen, sheep, hens, geese, and other poultry, and one breed of sheep, whose tails weigh between thirty and forty pounds. The capital city is also called Melinda.

MELINUM, in *Natural History*, the name of an earth famous in the earliest ages of painting, being the only white the great painters of antiquity used; and, according to Pliny's account, one of the three colours with which alone they performed all their works. From the description given of this earth it seems to have been aluminous, tolerably pure, and in a state of minute division.

MELISSA, in fabulous history, a daughter of Melissus king of Crete, who with her sister Amalthœa fed Jupiter with the milk of goats. She first found out the means of collecting honey, and hence it has been fabled that she was changed into a bee, as her name is the Greek word for that insect.

MELISSUS, a philosopher of Samos, was the disciple of Parmenides and Heraclius; he flourished B.C. 444, and was the contemporary of Zeno of Velia, and Empedocles. He did not confine himself to the abstruse questions of philosophy, but took an active part in the political affairs of his country. We find him commanding the fleet of his native island against Pericles, B.C. 440, but he did not succeed in preventing the island from falling into the hands of the Athenians. (Plut. *Pericl.* c. 26, 27.) Melissus supposed that the universe was infinite, unchangeable, and immoveable. He denied the reality of motion, maintaining that it was merely a deception of the senses. Of the gods he maintained that we know nothing, and therefore cannot enter into a discussion respecting their power and attributes. (*Diogenes Laërt.* l. ix.) He was the author of a work, περι του ὀντος, on Nature, of which Eusebius has preserved a fragment in his *Præparatio Evangelii*, xiv.; and another, *De Animalibus*, of which Fulgentius has inserted in his mythology what Melissus mentions respecting the swan. Fabricius, *Biblioth. Græca*, i. p. 820.)

MELITO, a canonized bishop of Sardis in Lydia, in the second century, remarkable for the apology he presented to the emperor Aurelius, in favour of the Christians, on which Eusebius and the other ancient ecclesiastical writers bestow great praises. But that apology, and indeed all Melito's other works are now lost.

MELITUS, a Greek orator and poet, the accuser of Socrates. The Athenians, after the death of Socrates, having discovered the iniquity of the sentence which they had passed against that great philosopher, put Melitus to death, 400 B.C.

MELKAPOOR, a town of Hindustan in the Nizam's territories, in the province of Berar, twenty-eight miles south-east from Boorhanpour. Long. 76. 39. E. lat. 21. 4. N.

MELKSHAM, a town of the county of Wilts, in the hundred of the same name, ninety-nine miles from London, and situated on one of the great roads to Bath. It is a well

Melle ‖ Melmoth.

built town, chiefly inhabited by persons employed in making fine cloths and cassimeres. It has a cattle market, which is held on alternate Thursdays, but none for provisions is regularly held. The inhabitants were in 1801, 4030; in 1811, 4110; in 1821, 4765; and in 1831, 4722.

MELLE, an arrondisement of the department of the two Sèvres in France, extending over 573 square miles. It contains seven cantons, divided into ninety-eight communes, and is inhabited by 63,800 persons. The capital is the city of the same name, situated on the river Beronne. It contains 300 houses, and 1890 inhabitants.

MELMOTH, William, a learned member of Lincoln's Inn, was born in the year 1666. In conjunction with Mr. Peere Williams, Mr. Melmoth was the publisher of Vernon's Reports, under an order of the court of Chancery. He had once an intention of printing his own reports, and a short time before his death advertised them at the end of those of his coadjutor Peere Williams, as then actually preparing for the press. They have not yet, however, made their appearance. But the performance for which he justly deserves to be held in perpetual remembrance is, The Great Importance of a Religious Life; concerning which it may be mentioned to the credit of the age, that notwithstanding many large editions had before been circulated, 42,000 copies of this useful treatise have been sold in the course of eighteen years. It is a somewhat singular circumstance, that the real author of this most admirable treatise should never before have been publicly known: it had been commonly attributed to the first Earl of Egmont, particularly by Mr. Walpole in his Catalogue; which is the more surprising, as the author is plainly pointed out in the short character prefixed to the book itself. "It may add weight, perhaps, to the reflections contained in the following pages," we are told, "to inform the reader, that the author's life was one uniform exemplar of those precepts which, with so generous a zeal, and such an elegant and affecting simplicity of style, he endeavours to recommend to general practice. He left others to contend for modes of faith, and inflame themselves and the world with endless controversy; it was the wiser purpose of his more ennobled aim, to act up to those clear rules of conduct which revelation hath graciously prescribed. He possessed by temper every moral virtue; by religion every Christian grace. He had a humanity that melted at every distress; a charity which not only thought no evil, but suspected none. He exercised his profession with a skill and integrity which nothing could equal but the disinterested motive that animated his labours, or the amiable modesty which accompanied all his virtues. He employed his industry, not to gratify his own desires; no man indulged himself less: not to accumulate useless wealth; no man more disdained so unworthy a pursuit: it was for the decent advancement of his family, for the generous assistance of his friends, for the ready relief of the indigent. How often did he exert his distinguished abilities, yet refuse the reward of them, in defence of the widow, the fatherless, and him that had none to help him. In a word, few have ever passed a more useful, not one a more blameless life; and his whole time was employed either in doing good, or in meditating it. He died on the 6th day of April 1743, and lies buried under the cloister of Lincoln's Inn chapel."

Melmoth, William, son of the preceding, was born in 1710. Of his early history little is known, nor do we find that he studied at either university, though it is probable that he received a liberal education. He was bred to the law, and appointed a commissioner of bankrupts in 1756; but the greater part of his life was spent in retirement from public business, partly at Shrewsbury, and partly at Bath, where he was not less distinguished for integrity of conduct, than for polished manners and elegant taste. He first appeared as a writer about the year 1742, when, under the name of Fitzosborne, he published a volume of Letters, which have been much admired by some for their style, though it is overlaboured and devoid of natural fluency, and by others for the just and liberal remarks with which they abound, on various topics, moral and literary. In 1747, he published his translation of the Letters of Pliny, in two vols. 8vo, which was then and is still regarded as one of the best versions of a Latin author that has appeared in our language. It is remarkable alike for elegance, precision, and correctness; the translator enters with rare felicity into the spirit not only of the author's ideas, but of his style, the characteristic attributes of which he has faithfully transfused; the freedom, ease, and graceful familiarity of the epistolary style are happily preserved; and there are few instances to be found in any language where an original has suffered so little in passing through the trying alembic of translation. In 1753, he published a translation of Cicero's Letters to several of his Friends, with remarks, in three volumes; and he likewise translated the treatises *De Amicitia*, and *De Senectute*, which were published in 1773 and 1779, and enriched with annotations, literary and philosophical, which added greatly to their value. In his remarks on the treatise *De Amicitia*, he combated the opinion of Lord Shaftesbury, who had imputed it to Christianity as a defect, that it contained no precepts in favour of friendship; and also that of Soame Jenyns, who had represented this very omission as a proof of its divine origin. His refutation, in both instances, rests upon solid grounds. Lord Shaftesbury's notion is founded on a total misconception of the true character and aim of the Christian religion; the paradox of Soame Jenyns proceeds on an oblivion of its first and greatest precept. The same just and orthodox spirit he had previously evinced in his reply to Mr. Bryant, who, in his Treatise on the Truth of the Christian Religion, had attacked Mr. Melmoth's remarks on Trajan's persecution of the Christians in Bithynia, contained in a note to his translation of Pliny's Letters. The concluding work of Mr. Melmoth was a tribute of filial affection, and consisted in Memoirs of his father, published in 1796. After a long life passed in literary pursuits, and in the exercise of private virtue, this excellent and accomplished person died at Bath on the 15th of March 1799, at the age of eighty-nine. He had been twice married; first, to the daughter of Dr. King, principal of St. Mary's Hall, Oxford; and, secondly, to a widow lady, named Mrs. Ogle. Mr. Melmoth was a happy example of the mild and humanizing influence of learning on a cultivated mind; we mean of that learning which is described by the great Roman orator as constituting "the aliment of youth, and the delight and consolation of declining years." "Who," says the author of the Pursuits of Literature, "who would not envy this fortunate old man his most finished translation and comment on Tully's Cato? or rather who would not rejoice in the refined and mellowed pleasure of so accomplished a gentleman, and so liberal a scholar?" Dr. Warton, in a note on Pope's works, mentions Melmoth's translation of Pliny's Letters as "one of the few that are better than the original;" and Birch, in his Life of Tillotson, makes nearly the same observation. Both have perhaps exceeded just bounds in pronouncing so unqualified an eulogium; but such an opinion deliberately expressed by such men, affords strong presumptive evidence in support of the more limited commendation which we have above ventured to bestow; and there can be no doubt whatever, that Melmoth is one of the few translators who have been successful in producing an "express image" of their originals. Besides the works already mentioned, Mr. Melmoth composed some poetical pieces, which were inserted, one of them in Dodsley's, and three in Pearch's poems, but none of them possesses any peculiar merit, or rises above a decent mediocrity. The fame of Melmoth rests on his prose alone. (A.)

Melody.

MELODY, in *Music*, a succession of sounds ranged in

Melody.

such a manner, according to the laws of rhythm and modulation, that it forms a sentiment agreeable to the ear. Vocal melody is called *singing;* and that which is performed upon instruments has been termed *symphonic melody.*

The idea of rhythmus necessarily enters into that of melody. An air is not an air but in proportion as the laws of measure and quantity are observed. The same succession of sounds is susceptible of as many different characters, as many different kinds of melody, as the various ways by which its emphatic notes, and the quantities of those which intervene, may be diversified; and the change in duration of the notes alone, may disguise that very succession in such a manner that it cannot be known. Thus, melody in itself is nothing; it is the rhythmus or measure which determines it, and there can be no air without time. If then we abstract measure from both, we cannot compare melody with harmony; for to the former it is essential, but not at all to the latter.

Melody, according to the manner in which it is considered, has a relation to two different principles. When regarded only as agreeable to the proportions of sound and the rules of modulation, it has its principle in harmony; since it is an harmonical analysis, which exhibits the different gradations of the scale, the chords peculiar to each mode, and the laws of modulation, which are the sole elements that compose an air. According to this principle, the whole power of melody is limited to that of pleasing the ear by agreeable sounds, as the eye may be pleased by an agreeable assemblage of suitable colours. But when considered as an imitative art, by which we may affect the mind with various images, excite different emotions in the heart, inflame or soothe the passions, and produce different effects upon our moral faculties, which cannot be produced by the influence of external sense alone, we must explore another principle for melody; for in our whole internal frame there appears to be no power upon which either harmony alone, or its necessary results, can seize, to affect us in such a manner.

What, then, is the second principle? It is as much founded on nature as the first; but, in order to discover its foundation in nature, it will require a more accurate though simple observation, and a more exquisite degree of sensibility in the observer. This principle is the same which varies the tone of the voice, when we speak, according as we are interested in what we say, and according to the different emotions which we feel in expressing it. It is the accent of languages which determines the melody of every nation; it is the accent which leads us to employ the emphasis of speaking whilst we sing, and to speak with more or less energy according as the language which we use is more or less accented. That language the accents of which are the most sensible, ought to produce the most passionate and lively melody; that which has little accentuation, or none at all, can only produce a cold and languid melody, without character and without expression. These are the true principles. In proportion as we depart from them, when we speak of the power of music upon the human heart, we shall become unintelligible to ourselves and others; our words will be without meaning.

If music does not impress the soul with images except by melody, if it thence obtains its whole power, it must follow, that all musical sounds which are not pleasing by themselves alone, however agreeable to harmony they may be, do not form an imitative music; and, being incapable, even with the most beautiful chords, either of presenting the images of things, or exciting the finer feelings, very soon cloy the ear, and leave always the heart in cold indifference. It follows likewise, that notwithstanding the parts which harmony has introduced, and which the actual taste of music so wantonly abuses, wherever two different melodies are heard at the same time, they counteract each other, and destroy the effects of both, however beautiful each may be when performed alone. From this it may be judged with what degree of taste the French composers have introduced into their operas the miserable practice of accompanying one air with another, as well in singing, as in instrumental performances.

Melos ‖ Melrose.

But the causes by which national melody is diversified and characterized, are more profound and permanent than the mere accentuation of language. This indeed may have great influence in determining the nature of the rhythm, and the place of emphatic notes, but very little in regulating the nature of the emphasis and expression themselves. If Rousseau's principle be true in its full extent, it must of necessity be acknowledged, that an air which was never set or intended for words, however melodious, cannot be imitative; that what is imitative in one nation cannot be so in another; and that, upon his hypothesis, the recitative, which is formed upon the mode of speaking, is the most forcible of all melodies, which is absurd. But his other observations are at once judicious and profound. Though it is impossible to exhibit the beauty and variety of harmony by playing the same melody at the same time upon different keys, admitting those keys to form amongst themselves a perfect chord, which will of consequence preserve all the subsequent notes in the same intervals; yet this perfect harmony would by no means be uniformly pleasing to the ear. We must therefore of necessity introduce less perfect chords to vary and increase the pleasure, and these chords in any complex system of music must of necessity produce dissonances. It then becomes the business of the composer to be careful that these discords may arise as naturally from, and return as naturally to, perfect harmony as possible. These causes must inevitably have the effect of varying the melody of the different parts; but still, amidst all these difficulties, the artist ought to be zealous in preserving the melody of each as homogeneous with others as possible, that the result of the whole may be in some measure uniform. Otherwise, by counteracting each other, the parts will reciprocally destroy their effects.

MELOS, in *Ancient Geography*, an island situated between Crete and Peloponnessus, about twenty-four miles from Scyllæum. It is about sixty miles in circumference, and of an oblong figure. It enjoyed its independence for about 700 years before the time of the Peloponnesian war. This island was originally peopled by a Lacedæmonian colony, 1116 years before the Christian era; and hence the inhabitants refused to join the rest of the islands and the Athenians against the Peloponnesians. But this refusal was severely punished. The Athenians took Melos, and put to the sword all those who were able to bear arms. The women and children were made slaves, and the island left desolate. An Athenian colony repeopled it, till Lysander reconquered the island, and re-established the original inhabitants in their possessions.

MELPOMENE, in fabulous history, one of the muses, daughter of Jupiter and Mnemosyne, who presided over tragedy. Horace has addressed the finest of his odes to her, as to the patroness of lyric poetry. She was generally represented as a young woman with a serious countenance; her garments were splendid; she wore a buskin, and held a dagger in one hand, with a sceptre and crown in the other.

MELROSE, a village in the parish of Melrose in Roxburghshire, on the south side of the river Tweed, near the northern base of the Eildon hills, and thirty-five miles from Edinburgh. It is pleasantly situated in a picturesque and fertile country, the scene of many a border legend; the streets form a kind of triangle, in the centre of which stands the cross, a structure supposed to be coeval with the abbey itself. The cross is supported by the endowment of a small portion of land, called the Corse-rig, which the proprietor holds upon the sole condition of "keeping up the cross." Melrose Abbey must have first occasioned the rise of the

Melton Mowbray.

village, and continues to be its chief support to the present day; it was founded by King David I. in 1136, and dedicated to the Virgin Mary; and it was furnished with monks of the Cistercian order from Rivale Abbey in Yorkshire. The nave which lies due east and west is in length 258 feet, and in breadth 79 feet; at the distance of fifty feet from the eastern extremity it is intersected at right angles by the transept which is 130 feet in length, and 44 in breadth. The pious founder, whom James VI. calls a "sair sainct for the croune," conferred extensive lands and valuable privileges on the abbot and monks of this abbey, which was one of the most magnificent institutions of the kind in Scotland. They held by charter the lands of Melrose, Eldun, and Dernervie, the lands and wood of Gattonside, with the fishings of the Tweed along the whole extent of those lands, the right of pasturage and pannage in the king's forests of Selkirk, Traquair, and in the forest lying between the Gala and the Leader, and also the privilege of taking wood for building and burning, from the same forests. During the twelfth and thirteenth centuries, the piety of princes and nobles continued adding to the privileges and wealth of the monks of Melrose, who accumulated vast possessions in Ayr, Dumfries, Selkirk, Berwick, and other places. Monastic institutions were generally considered as sacred by contending parties, and thus the protection afforded by the abbey of Melrose must have been exceedingly serviceable in a district peculiarly exposed to the marauding incursions of barbarous freebooters, and which was the field of frequent sanguinary conflicts, infuriated by national antipathies and personal wrongs. Being situated, however, close by the hostile borders, it could hardly be expected that it should always escape. In 1322 the abbey was burned by Edward II., and several of the monks, with William de Peebles, the abbot, were slain. It was repaired and endowed with most munificent grants by Robert Bruce, whose heart was buried here, after the unsuccessful attempt to have it deposited in the holy sepulchre at Jerusalem.

During the reformation in England under Henry VIII., the dilapidation of the monasteries in the south of Scotland commenced. In 1545 a great part of the Abbey of Melrose was destroyed by Sir Ralph Eure and Sir Bryan Layton. In the same year, Melrose, with its monastery, was again wasted by the English army under the Earl of Hertford, and in a few years afterwards it became the prey of the Scotish reformers. The act of annexation first placed the lands and revenues of this wealthy establishment in the hands of Queen Mary; they then passed to various favourites of royalty, until at length the abbey and a great part of its domains were acquired by the family of Buccleuch. The ruins of the monastery afford the finest specimens of Gothic architecture and Gothic sculpture of which this country can boast; and it is singularly fortunate that this is not only one of the most exquisitely beautiful, but one of the most entire of the ecclesiastical ruins in Scotland. Till within these few years the abbey was used as the parish church; there is now, however, a church built at some distance from it, and the abbey has been disincumbered of the clumsy and discordant galleries or lofts erected for the accommodation of the congregation. The rents of this abbey at the reformation were, in money, £1758 Scots; in wheat, 19 chalders, 9 bolls; in bear, 77 chalders, 3 bolls; in oats, 47 chalders, 1 boll, 2 firlots; meal, 14 chalders, with 8 chalders of salt, 105 stones of butter, 10 dozen of capons, 26 dozen of poultry, 376 muirfowl, and 360 loads of peats. Alexander II. was buried beneath the great altar, and the remains of many of the illustrious line of Douglas rest within the abbey, which was also the place of interment of other powerful families. The population of the village of Melrose, in 1835 amounted to 689.

MELTON MOWBRAY, a town of the county of Leicester, in the hundred of Frankland, 104 miles from London. It stands on the river Eye, is well built, and has a good free school. It is celebrated on account of the various establishments for keeping hunters belonging to noblemen and gentlemen of fortune, who repair hither to enjoy in the highest style the amusement of fox-hunting. Two packs of the best bred hounds are kept here by subscription. There is a large market on Thursday. The population was, in 1801, 1766; in 1811, 2145; in 1821, 2815; and in 1831, 3356.

Melun ‖ Melville.

MELUN, an arrondisement of the department of the Seine and the Marne, in France. It extends over 442 square miles, is divided into six cantons, and they into 107 communes, containing 54,500 inhabitants. The capital is a city of the same name, situated on the Seine; it contains 820 houses, and 6400 inhabitants, who make cotton goods, some glass, and carry on tanneries. Lat. 48. 59. 40. N. Long. 21. 31. 25. E.

MELVILLE, Andrew, a Scotish divine of distinguished talents and learning, was born at Baldovy in Forfarshire on the 1st of August 1545. His father, Richard Melville, was brother to Melville of Dysart, and was thus connected with a family which boasted its descent from the blood royal, although the genealogical lines do not seem to be very distinctly traced. His mother was Giles, the daughter of Thomas Abercromby, a burgess of Montrose. In the immediate vicinity of this town the father possessed the small demesne of Baldovy, and might have been able to rear his family with sufficient credit and comfort, but having been called to arms in the ordinary course of feudal service, he was slain at the disastrous battle of Pinkey, fought on the 10th of September 1547. Andrew, the youngest of nine sons, had only completed the second year of his age; and his mother having died in the course of that year, the care of the orphan boy devolved upon his eldest brother Richard, who afterwards became minister of the adjacent parish of Marytoun. The place of both parents was fully supplied by this brother and his wife, who reared him with the most affectionate care. When he reached a mature age, he frequently recounted in terms of the warmest gratitude the many instances of maternal tenderness and fondness which he had experienced from his excellent sister-in-law. As he was a sickly child, and discovered great aptitude for learning, his guardian adopted the fortunate resolution of securing to him all the attainable advantages of a liberal education. He was accordingly removed to Montrose school, of which Thomas Anderson, afterwards the protestant minister of that parish, was at that time master. Here he was instructed in the rudiments of the Latin language; and as bodily exercise was duly intermingled with his more sedentary avocations, his constitution acquired a much firmer tone, and he afterwards enjoyed a large share of good health.

In the year 1559 he was sent to the university of St. Andrews, where he became a student in St. Mary's College, and greatly distinguished himself by his early proficiency in classical learning. At that period the course of literature and philosophy chiefly consisted of lectures on Aristotle's logic, rhetoric, ethics, and physics; but this course must have been rendered very defective by the circumstance of the professor's being altogether unacquainted with the original text, and being thus reduced to the necessity of commenting upon Latin translations or compendiums. Melville was dissatisfied with this imperfect method of procedure, and applied himself so assiduously to the study of Greek, that he was speedily enabled to read in that language all the texts of Aristotle to which the college lectures referred. To what preceptor he was indebted for private instructions, or whether he solely relied on his own exertions, we are not sufficiently informed. It is however certain that he acquired no small reputation by his proficiency in a department of elegant learning which was then so little cultivated; and it may here be recorded to the credit of his masters, that they warmly encouraged him to tread in a path in

Melville. which they themselves could not lead, and in which they were scarcely prepared to follow. The provost of St. Mary's, John Douglas, who was likewise rector of the university, treated him with paternal kindness, and seems to have entertained some anticipation of his eminence in letters. In this college there were separate classes for grammar and rhetoric; and there were also lectures by the law professor, which the students might attend before taking their higher degree. Of all the public and private opportunities of improvement Melville seems to have availed himself to the utmost extent; and he left this university with the reputation of "the best philosopher, poet, and Grecian of any young master in the land."[1] It would therefore appear that he had already displayed those talents for Latin poetry which were afterwards so conspicuous. The unrivalled celebrity of Buchanan must have had a strong tendency to excite the emulation of his young and ingenuous countrymen. Melville speaks of this illustrious man as having been his preceptor; but whether the expression is to be understood according to its literal signification, we cannot so easily ascertain. In 1561 Buchanan returned to his native country, and in 1567 he became principal of St. Leonard's College; but the young scholar had then quitted the university, and could therefore receive no instructions from him at St. Andrews.

In the autumn of 1564, when he had completed the nineteenth year of his age, he proceeded to Paris with the view of prosecuting his studies in a place which afforded much greater opportunities of intellectual improvement. That university had then attained to the height of its celebrity, and the reported number of students who frequented it seems almost to exceed belief: Joseph Scaliger mentions, that, during his own residence, it contained the astonishing number of thirty thousand. Melville enjoyed the eminent advantage of hearing the prelections of Turnebus, professor of Greek in the Royal College. He had thus an excellent opportunity of being initiated in the critical study of classical authors; and under the guidance of Mercier and Quinquarboreus, conjunct professors of Hebrew and Chaldee, he applied himself with equal assiduity to the acquisition of those languages. Nor did he neglect the lectures of Ramus, royal professor of Roman eloquence; who had greatly distinguished himself by his strenuous opposition to the philosophy of Aristotle, and who seems to have given a considerable impulse to the minds of his contemporaries. He likewise studied under several other professors, whose names are mentioned by his nephew; nor did he confine his views to one or two departments of science or literature; mathematics, law, and physic, all succeeded each other in due order. Till a much later period, the civil law was not regularly and publicly taught in the university of Paris, but a dispensation for teaching it was occasionally obtained; and it was at that time taught by Balduinus, or Baudouin, a very eminent civilian, who numbered this ardent youth among his pupils. During the second year of his residence, he had attained to such proficiency in the Greek language, that he was able to speak it with great fluency and copiousness. Having thus made a large accession to his stock of learning, he quitted Paris in the year 1566, and repaired to the university of Poitiers, where he prosecuted the study of law. Here he was appointed a regent in the College of St. Marceon; and though he was only twenty-one years of age, he appears to have acquitted himself with the highest credit. But the renewal of the civil wars, by which France was so long devastated, speedily rendered his situation uncertain and perilous. In the year 1568 the city was besieged by a protestant army under Coligny, and was defended by a popish garrison under the duke of Guise. The business of the university was necessarily suspended, and Melville was then engaged by a counsellor of the parliament, in the capacity of tutor to his only son. He was a boy of an amiable disposition, and of promising talents, but the fond hopes of his parents and of his preceptor were very suddenly blasted: he was mortally wounded by a cannon ball, and Melville found him weltering in his blood. He had received lessons of piety as well as literature, and with his dying breath he testified his affection for his instructor; who to the latest period of his life retained a very lively and tender recollection of his young friend, so prematurely lost. The casualties of war were not the only dangers to which he was exposed: a corporal who was stationed in the house with a few soldiers, having observed his habits of devotion, concluded that he must be a Huguenot, and expressed an opinion that he might be disposed to betray the city to the enemy; but he had sufficient address and presence of mind to dissipate all his suspicions, nor was he again subjected to any similar annoyance. The siege having at length been raised, he quitted Poitiers, after a residence of three years, and directed his course towards Geneva. Leaving behind him his books and other effects, and fixing a small Hebrew Bible in his girdle, he began his journey in company with a Frenchman. They travelled on foot, and our countryman proceeded with great alacrity; for, as his nephew informs us, "he was small and light of body, but full of spirit, vigorous and courageous." On reaching the place of his destination, he immediately waited upon Beza; and his first appearance made so favourable an impression, that he was at once considered as a person well qualified to fill the humanity chair, which at that time happened to be vacant. Within a few days after his arrival, he so ably performed the probationary exercises in Homer and Virgil, that he was without hesitation admitted to the professorship. A quarter's salary, paid by advance, came very seasonably to his aid; for when the two travellers reached the gates of the city, they could scarcely muster a crown between them; and his own necessities being thus relieved, he was enabled to support his less fortunate companion till he found some more permanent provision. Melville.

Geneva was at this momentous crisis a most conspicuous bulwark of the reformation. The territories of the state were very circumscribed, and its resources proportionally limited; but the virtue of the people, with the wisdom and energy of its rulers, secured to this little republic a more honourable fame than power or arms could have bestowed. It afforded an asylum to many of the persecuted protestants who rendered its walls venerable by their piety and learning. The academy of Geneva, which was a university without the name, could boast of various professors of the highest reputation. Calvin, the first professor of divinity, was distinguished by his genius and eloquence as well as by his learning. His chair was now occupied by Beza; who was likewise a man of eminent talents, and who with his profound knowledge of theology united many of the graces of polite literature. He had been a gay and lively poet in his early youth, nor did he discontinue his intercourse with the Muses at a very advanced age. Melville, who had only attained the age of twenty-five, and who was not less eager to learn than willing to teach, became a student under this able and venerable professor. Notwithstanding the disparity of their years, they formed a cordial friendship with each other. From Bertram, the professor of oriental languages, he acquired a knowledge of Syriac. The Greek professor was Franciscus Portus, a native of Candia, who was very familiarly acquainted with the ancient language of his native country; but, like all the modern Greeks, he pronounced it according to accent, and with a total disregard of quantity. In their friendly intercourse with each other, Melville ventured to dispute the propriety of this practice, and some-

[1] The Diary of James Melville, p. 31. Edinb. 1829, 4to.

Melville. times provoked him to exclaim, "You Scots, you barbarians, will, forsooth, teach us Greeks the pronunciation of our own language!" The professor of the civil law was Henry Scrimger, who was greatly distinguished by his classical learning, as well as by his knowledge of ancient jurisprudence. He was educated at St. Andrews, Paris, and Bourges, and after having been employed as tutor to the sons of Bochetel, the French secretary of state, he was engaged as private secretary to the bishop of Rennes, whom he accompanied on his embassy to different courts of Italy. At a subsequent period he resided at Augsburg, where he was retained by Ulrich Fugger, a member of a family conspicuous for its opulence, and for its munificent encouragment of learning. He was employed in collecting rare books and manuscripts for this gentleman's magnificent library. His attachment to the reformed doctrines had induced him to abandon a fair prospect of advancement in France; and Calvin having invited him to Geneva, he was admitted to the freedom of the city, and was appointed professor of philosophy in the academy. After retaining the office for two years, he exchanged it for the professorship of the civil law. This chair he filled till the time of his death, and he left behind him the character of a very learned and worthy man. His different employments had enabled him to acquire considerable wealth; and at the distance of a league from Geneva he built a neat villa, called Vilet, and collected a valuable library, which included many ancient manuscripts. He had earned the reputation of an excellent Grecian, and had devoted much labour to the illustration of Greek authors; but the only work of this denomination which he lived to publish was an edition of the *Novellae Constitutiones* of Justinian and other emperors, elegantly printed by his friend H. Stephanus in the year 1558. A sister of Scrimger had married Melville's eldest brother; and this family connexion must have had a tendency to strengthen the attachment of two individuals who were likewise mutually attracted by their common love of letters.

In the year 1572 the atrocious massacre of St. Bartholomew spread such dismay among the French protestants, that many of them were induced to abandon their native country. Geneva was crowded with these refugees; and at one time it contained no fewer than one hundred and twenty French ministers. "The academy," as Dr. M'Crie has stated, "overflowed with students, and the magistrates were unable to provide salaries for the learned men whom they were desirous to employ, or to find situations for such as were willing to teach without receiving any remuneration." It was at this period that Joseph Scaliger, who bears the first name in the annals of modern erudition, was appointed a professor of philosophy. He had paid a visit to Geneva two years before, and Melville had then been honoured with his acquaintance. He entered upon his professorship in the month of October 1572, and resigned it after an interval of two years. The academy derived additional lusture from the presence of Hotman and Bonnefoy, two very learned civilians, who had likewise fled from the daggers of the assassins, and who experienced the same cordial reception and liberal treatment. To the former the magistrates allotted a salary of 800, and to the latter a salary of 700 florins a year: Hotman lectured twice a-week on the civil law, and Bonnefoy thrice a-week on the oriental jurisprudence, that is, the jurisprudence, secular and ecclesiastical, of the Greek empire; a branch of study to which he had devoted much attention, and which he illustrated in a work published in the year 1573. It is expressly stated that Melville attended the lectures of Hotman; and, as his excellent biographer suggests, "there can be little doubt that he also availed himself of the opportunity of attending those of Bonnefoy, which were still more intimately connected with those studies to which he had now devoted his chief attention." Melville.

After having retained his professorship for five years, he was at length induced to revisit his native country. Some of his own relations had warmly solicited his return; and their arguments were strenuously seconded by Andrew Polwarth, with whom he had been acquainted at St. Andrews, and who had now arrived at Geneva as travelling tutor to Alexander Campbell, the youthful bishop of Brechin. The magistrates of the city and the professors of the academy were reluctant to be deprived of the services of a scholar who had already afforded sufficient indications of his talents and learning. Beza addressed to the general assembly a letter in which he stated, that, as the greatest token of affection which the church of Geneva could shew to the church of Scotland, they had suffered themselves to be deprived of Andrew Melville, in order that his native country might be enriched by his gifts. The bishop and his fellow-travellers having commenced their journey in the spring of 1574, traversed Franche Comté, and, proceeding by Lyon, sailed down the Loire to Orleans. On their arrival at Paris, Melville, at the suggestion of Lord Ogilvy, visited the College of the Jesuits, and was there engaged in a controversy with James Tyrie, one of the antagonists of Knox. Their disputation was renewed for several successive days, and might have been of longer duration, if the archbishop of Glasgow had not used some threatening expressions which induced the friends of Melville to hasten his departure. He quitted the French metropolis on the 30th of May, in company with the bishop and his tutor. Having embarked at Dieppe, they landed at Rye, and proceeded to London, where they remained for only a short time; and having then purchased horses, they pursued their journey by way of Berwick, and arrived at Edinburgh in the beginning of July 1574.

Melville had already distinguished himself by his Latin poetry, and his reputation as a man of talents had reached his native country.[1] The earl of Morton, regent of the kingdom, was desirous of retaining him in the capacity of a domestic chaplain; and very soon after his arrival, George Buchanan, Alexander Hay, clerk of the privy council, and Colonel James Halyburton, were the bearers of such a proposal, which however he did not think it expedient to accept. He had no wish to become a courtier; and he was persuaded that his labours would be most available to his countrymen, if he were placed in one of the universities. In the mean time, he paid a visit to his brother Richard at Baldovy; where he devoted some portion of his time to the instruction of his nephew James Melville, who had recently taken his master's degree at St. Andrews, but who found that his uncle was a teacher very unlike those by whom he had previously been trained. His services however were speedily required in a different station. On the death of John Douglas, who had accumulated the offices of archbishop of St. Andrews, provost of St. Mary's College, and rector of the university, a proposition was made for placing him at the head of the college; but on being very strongly urged to accept of a similar appointment at Glasgow, he was finally induced to give it the preference. Having visited the scene of his future labours, he returned to Baldovy, and again left it about the end of October. Accompanied by his brother John and by his nephew, he proceeded by way of Stirling, where he spent two days, and was gratified with an opportunity of seeing the young king, then in the ninth year of his age. Here "he conferred at

[1] It was about this period that he published his earliest work: "Carmen Mosis, ex Deuteron. cap. xxxii. quod ipse moriens Israeli tradidit ediscendum et cantandum perpetuo, Latina paraphrasi illustratum. Cui addita sunt nonnulla Epigrammata, et Jobi cap. iii. Latino carmine redditum. Andrea Melvino Scoto auctore." Basileæ, 1574, 8vo.

Melville. length" with Buchanan, the king's preceptor, who was then engaged in writing his History of Scotland; and here he likewise met with Dr. Moncreiff, with whom he had been well acquainted at Geneva. Thomas Buchanan, the nephew of his illustrious friend, accompanied him to Glasgow; where he was immediately installed in the office of principal, and where he found the university in a very unprosperous condition. When he commenced his academical labours, about the beginning of November 1574, his only coadjutor was Peter Blackburne, who officiated as a regent, and managed the scanty revenues of the foundation. Of the prodigious exertions of the principal himself, the following enumeration will enable us to form a correct estimate. We are first of all informed, that he initiated his students in the principles of Greek grammar. "He then," says Dr. M'Crie, "introduced them to the study of logic and rhetoric; using as his text-books, the Dialectics of his Parisian master, Ramus, and the Rhetoric of Talaeus. While they were engaged in these studies, he read with them the best classical authors, as Virgil and Horace among the Latins, and Homer, Hesiod, Theocritus, Pindar, and Isocrates, among the Greeks; pointing out, as he went along, their beauties, and illustrating by them the principles of logic and rhetoric. Proceeding to mathematics and geography, he taught the Elements of Euclid, with the arithmetic and geometry of Ramus, and the geography of Dionysius. And agreeably to his plan of uniting elegant literature with philosophy, he made the students use the Phænomena of Aratus, and the Cosmographia of Honter. Moral philosophy formed the next branch of study; and on this he read Cicero's Offices, Pardoxes, and Tusculan Questions, the Ethics and Politics of Aristotle, and certain of Plato's Dialogues. In natural philosophy he made use of Fernelius, and commented on parts of the writings of Aristotle and Plato. To these he added a view of universal history, with chronology and the art of writing. Entering upon the duties of his own immediate profession, he taught the Hebrew language, first more cursorily by going over the elementary work of Martinius, and afterwards by a more accurate examination of its principles, accompanied with a praxis upon the Psalter and books of Solomon. He then initiated the students into Chaldee and Syriac; reading those parts of the books of Ezra and Daniel that are written in Chaldee, and the epistle to the Galatians in the Syriac version. He also went through all the common heads of divinity, according to the order of Calvin's Institutions, besides giving lectures on the different books of Scripture. This course of study was completed in six years."[1] During the second year, his nephew became one of the regents, and instructed his pupils in Greek, logic, and rhetoric; and in the ensuing year he taught them mathematics and ethics. He was the first professor who in any of the Scotish universities had publicly read the Greek authors in the original. Another regent was afterwards added to this scanty establishment. In 1577 Blaise Laurie was appointed teacher of the Greek language and of Roman eloquence; James Melville of mathematics, logic, and ethics; Blackburne, who likewise held the office of *oeconomus*, of physics, and astronomy; while the learned principal, whose previous labours had been so multifarious, restricted himself to divinity and oriental languages. A separate teacher of Hebrew was appointed about the period of his removal from Glasgow. During the year last specified, the parsonage of Govan, situate in the immediate vicinity, was annexed to the university, and it then became his duty as principal to officiate in the parish church.

The learning, the talents and energy of Melville speedily raised this university from its ruinous condition, and secured for it the reputation of being the first seminary in the kingdom. Before he completed his second academical year, his celebrity as a public teacher had begun to be very widely diffused: students were afterwards attracted from all parts of the country, and among these were not a few graduates from St. Andrews, who were laudably disposed to learn what their former masters could not teach. Various individuals who afterwards rose to eminence were here trained under his discipline. In this catalogue we find the name of John Spotswood, archbishop of St. Andrews, who certainly did not regard his old master with any peculiar veneration: we likewise find the name of Andrew Knox, bishop of the Isles, and afterwards of Raphoe, with those of Sir Adam Newton, Sir James Fullerton, Sir Gideon Murray, and Sir Edward Drummond, who were all more or less conspicuous at court. Newton, a man of talents and learning, was the tutor, and afterwards the secretary of Prince Henry. Melville sustained the discipline of the university with great vigour and address, and he was frequently placed in situations which required the aid of both; for some of the students, connected with powerful families, were guilty of most flagrant insubordination, and collected a mixed multitude to overawe the principal and the rector. Two of those delinquents were Mark Alexander Boyd, related to the noble family of that name, and Alexander Cunningham, related to the earl of Glencairn, who both proceeded to acts of outrageous violence, and being supported by many other disorderly youths, as well as by many adherents of their respective families, were at first disposed to set all academical authority at open defiance. Cunningham, who had assaulted J. Melville with a drawn sword, was finally reduced to the necessity of making a public and humiliating apology, with his feet as well as his head uncovered. John Maxwell, a son of Lord Herries, had likewise been implicated in some very disorderly proceedings; but when his father was informed of this conduct, he hastened to Glasgow, and compelled him, on his knees, and in an open area of the college, to beg the principal's pardon.

Melville's influence in advancing the literature of his native country was great and lasting, nor was it less considerable in improving the condition of the Scotish church. A very motley species of episcopacy had been engrafted upon the reformation; and although the opulence, as well as the idleness and profligacy of the popish prelacy, was no longer retained, he perceived no advantage in the name and office of a bishop, in contradistinction to the name and office of a presbyter. The bishops of the apostolical age were presbyters, and the presbyters were bishops: with a variety in the name, there was no variety of office. He was a member of the general assembly convened at Edinburgh in March, as well as of that convened at the same place in August 1575. The lawfulness of episcopacy was debated in this latter assembly; and he there maintained the negative side of the question, in a speech which, as Spotswood admits, "was applauded by many." For the more mature discussion of this subject, the assembly appointed a committee of six; namely, Melville, Craig, and Lawson, on the one side, and Hay, Row, and Lindsay, on the other. After an interval of two days, they presented a report, in which they did not hold it expedient to answer the general question as to the lawfulness of such an episcopacy as was then established; but they declared "that they judged the name of a bishop to be common to all ministers that had the charge of a particular flock; and that by the word of God his chief function consisted in the preaching of the word, the ministration of the sacraments, and exercise of ecclesiastical discipline, with consent of his elders." If an unfit person should be nominated to the office of a bishop, they were of opinion that he ought to be tried and deposed by the gene-

[1] M'Crie's Life of Andrew Melville, vol. i. p. 72. Edinb. 1819, 2 vols. 8vo.

Melville. ral assembly. They however admitted that, in addition to the charge of their own flocks, it might be expedient to entrust some ministers with the power of superintending a certain district, and there exercising a limited and defined jurisdiction.[1] The report was finally and fully approved by the assembly held in April 1576; and those bishops who had not already undertaken some parochial cure, were enjoined to select particular parishes for the exercise of their pastoral functions. This was the first step towards the abolition of diocesan episcopacy, but more important measures were yet to follow. The regent was by no means satisfied with these proceedings; and during the assembly of October 1577, he sent for Melville with the view of remonstrating against some measures which were then in contemplation. Finding that all other suggestions were unavailing, Morton had recourse to threats, and exclaimed, "There will never be quiet in this country till half a dozen of you are hanged or banished." The resolution of Melville was as little to be shaken by threats as by promises; and he returned an undaunted and characteristic answer, which could not fail to convince the noble earl that he had not selected a proper subject for such an experiment. Of the assembly held in Magdalene chapel at Edinburgh in the month of April 1578, Melville was chosen moderator. The Second Book of Discipline now received the sanction of this ecclesiastical judicature; and although it was not ratified by the privy council or parliament, it was acknowledged by the church as exhibiting the standard of her polity. It was likewise resolved that bishops should no longer be described as *lords*, but should be addressed like other ministers. This purification of the church was completed by the assembly of Dundee, convened in July 1580; when they "found and declared the office of a bishop, as then used and commonly understood, to be destitute of warrant from the word of God, and a human invention tending to the great injury of the church." This important resolution passed without one dissenting voice.

After a residence of six years at Glasgow, Melville was removed to St. Andrews, where he was installed as principal of St. Mary's College, in the month of December 1580. The office which he had vacated was filled by Thomas Smeton, who was likewise a man of learning, and is still remembered as the author of an answer to the virulent libel of Archibald Hamilton. The university of St. Andrews had very recently been subjected to a salutary reform, and this college had been appropriated to the study of divinity. The office of primarius professor of divinity was then conjoined, as it still continues to be, with that of principal. John Robertson read lectures on the Greek Testament; and James Melville, who had accompanied his uncle from Glasgow, was appointed professor of oriental languages, and began by initiating the students in Hebrew. The parliamentary commissioners had provided for the establishment of two chairs, which however were not yet filled. A more laborious task was thus imposed upon the principal, who not only taught systematic theology, but likewise "taught learnedly and perfectly the knowledge and practice of the Hebrew, Chaldee, Syriac, and rabinical languages." In this new situation he had to contend with new difficulties. Robert Hamilton had been displaced to make room for Melville; some of the other regents were likewise superseded; and the professors of law and mathematics were removed from St. Mary's to St. Salvator's College. Here were some apparent grounds of private offence, and he had besides incurred the violent resentment of Aristotle's numerous friends; but his superior talents and learning, with the firmness and consistency of his personal character, enabled him to overcome all the unreasonable opposition which he had thus to encounter.

Melville.

Of the political events which marked this period of Scottish history he was not an unconcerned spectator. The young king had unfortunately placed himself under the sole direction of two papists, whom he created duke of Lennox and earl of Arran; and a design was entertained of associating his mother in the government, and eventually of restoring the popish religion in the kingdom. A very general alarm was excited among the protestants, who, by a solemn bond or covenant, engaged themselves to maintain with their estates and lives the liberties of their country, and the profession of the reformed religion. This instrument, prepared by John Craig, and dated in the year 1580, was subscribed by the king himself, as well as by individuals of all other ranks. The restoration of episcopacy was naturally favoured by those who favoured popery and arbitrary power. On the death of Archbishop Boyd, the disposal of the see of Glasgow was left to the duke of Lennox, who made a simoniacal bargain with Robert Montgomery, minister of Stirling. In the month of October 1581, his case was discussed in the general assembly; and the king having declared that it was competent to proceed against him for personal misconduct or erroneous doctrine, Melville rose and presented a libel, comprehending fifteen articles of accusation. The assembly directed the presbytery of Stirling to investigate these charges, and to report their decision to the synod of Lothian, which was formally authorized to pronounce his sentence. For acting according to these instructions, the members of the synod were summoned before the privy council; where, by the mouth of Robert Pont, one of their number, they declined the jurisdiction of that tribunal, as incompetent to take cognizance of a cause strictly ecclesiastical. An assembly was held at St. Andrews in April 1582, and Melville was again elected moderator. On their resuming the consideration of Montgomery's case, the master of requests presented a letter from the king, requiring them to desist from all further proceedings respecting the archbishopric of Glasgow, and a messenger-at-arms soon afterwards delivered a more peremptory denunciation. Instead of being deterred by the threatened pains and penalties of rebellion, they resolved to continue the investigation, and finally declared that the accused was liable to the sentence of deposition and excommunication; a sentence which it was not however necessary to pronounce, as he appeared before the assembly, and, having withdrawn his appeal, solemnly promised to refrain from all further attempts at obtaining possession of the archbishopric. But such was the levity of his disposition, that he speedily forgot his promise. He was censured by the presbytery of Glasgow, and excommunicated by that of Edinburgh. These bold and decided measures could not fail to incense the court: a proclamation, declaring the excommunication to be null and void, was issued by the privy council; such individuals as should refuse payment of rents due to his see were ordered to be committed to the castle of Inverness; the university of Glasgow, which had joined in the opposition to the new archbishop, was subjected to a temporary interdict; the ministers of Edinburgh, who had publicly animadverted on the recent proceedings of the king and his courtiers, were repeatedly cited before the privy council, where they were exposed to contumelious treatment; and John Dury, one of their number, was banished from the city, and prohibited from exercising his functions. An extraordinary meeting of the assembly was held in consequence of these violent proceedings, and Melville resumed his seat as moderator. On the occasion of their meeting he preached a sermon, in which he inveighed against those who had introduced the bloody knife "of absolute power into the country, and who sought to erect a new popedom in the person of the prince.

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[1] Spotswood's History of the Church of Scotland, p. 276. M'Crie's Life of Melville, vol. i. p. 160.

Melville. The pope, he said, was the first who united the ecclesiastical supremacy to the civil, which he had wrested from the emperor. Since the reformation, he had, with the view of suppressing the gospel, delegated his absolute power to the emperor, and the kings of Spain and France; and from France, where it had produced the horrors of St. Bartholomew, it was brought into this country." They now prepared a remonstrance, complaining of their grievances, and craving redress; and a deputation of the members, with the moderator at its head, was named for the purpose of presenting this remonstrance to his majesty, who was then residing at Perth. It was accordingly presented to the king in council; and on its being read, the earl of Arran asked with an angry countenance, "Who dare subscribe these articles?" "We dare," said the undaunted Melville, and immediately signed his name; nor did the other commissioners hesitate to follow his example. The minions of power were overawed by their intrepidity, and dismissed them without any formal censure.

Patrick Adamson had been appointed archbishop of St. Andrews in the year 1576; and, as he was a man of elegant learning, and a Latin poet, there was at least one bond of union between him and the principal of St. Mary's. For some time they lived on terms of good neighbourhood, and Melville frequently preached at his request. With the assistance of his nephew, he supplied the place of a parochial minister for a considerable period, during a long-protracted vacancy. This vacancy continued for upwards of three years; and although three different individuals, Pont, Smeton, and Arbuthnot, were successively chosen, not one of them was finally settled at St. Andrews. He did not fail to make public animadversions on the conduct of those who had laboured too successfully to prevent such a settlement; and he likewise augmented the number of his enemies, by his severity in rebuking the more flagrant and prevalent vices of the inhabitants. On one occasion, the provost of the city abruptly quitted the church in the middle of the sermon, not without muttering his high displeasure at the unsparing zeal of the preacher. The gates of St. Mary's College exhibited placards, threatening to bastinade the principal, to set fire to his lodgings, and to expel him from the city. But in the midst of these excitements he continued firm and undismayed; nor did he shrink from the decisive measure of summoning the provost before the presbytery, for contempt of divine ordinances. He was soon afterwards exposed to danger from another quarter. He was cited to appear before the privy council on the 17th of February 1584, to answer to the charge of having, on the occasion of a fast kept during the preceding month, uttered certain seditious and treasonable words in his sermon and prayers. Furnished with ample testimonials of his loyalty, he repaired to Edinburgh, and having appeared before the council, he entered into a full explanation and defence of the expressions which he had actually employed. They nevertheless resolved to proceed against him, when he stated six different grounds of objection. The most material of these was, that his case ought, in the first instance, to be remitted to the ecclesiastical court, as the ordinary and competent judicatory in all matters connected with his conduct as a minister. The proceedings having been adjourned to the following day, he then presented a written protest, declining the jurisdiction of the privy council, and embodying the same reasons which he had formerly urged. Deputations from the presbytery and from the university of St. Andrews were in attendance; the one for the purpose of entering a protest for saving the rights of the church, and the other for the purpose of repledging this head of a college to the court of the rector. They were not however permitted to execute their commission; and on the reading Melville. of Melville's declinature, the king and his minion Arran were roused to unseemly rage. But they had to deal with a man whom the frowns of royalty could not intimidate, and he pleaded his own cause with the most unshaken firmness and resolution. In the course of his speech he appealed to the authority of the scriptures; and unclasping a Hebrew Bible that was suspended at his girdle, he threw it on the council-table, and challenged any of his judges to shew that he had exceeded his instructions. He was repeatedly ordered to withdraw, but was not permitted to hold any communication with his friends. Several witnesses were examined, but nothing tending to criminate him could be extracted from their evidence. He was however found guilty of behaving irreverently before the council, and of declining its jurisdiction, and was sentenced to be imprisoned in the castle of Edinburgh, and to be further punished in his person and goods at the pleasure of the king. As he was not detained in custody, he had a brief interval for deliberating as to the most advisable course to be pursued; and his friends, as well as himself, were alarmed on ascertaining that his place of confinement was changed to Blackness castle, a dreary dungeon, kept by a dependant of the unscrupulous earl of Arran. Here his life would evidently have been exposed to danger; and finding it thus necessary to provide for his safety by flight, he secretly withdrew from Edinburgh, and next day proceeded to Berwick. This rigorous treatment of so learned and eminent a man excited no small degree of popular indignation. The ministers of Edinburgh had the courage to make mention of their exiled brother in their public prayers. With the view of removing the odium which had thus been incurred, the council issued a proclamation containing two averments that must have gained very little credence; namely, that he had been exposed to no danger of severe treatment, and that his exile was to be considered as voluntary. All these proceedings exhibit a glaring picture of the mode in which justice was then administered. We are not entirely disposed to think, with Dr. M'Crie, that Melville urged a good and valid plea when he averred that, in the first instance, he was only amenable to the jurisdiction of the ecclesiastical court. He was charged with having uttered seditious and treasonable words in the pulpit, and for such conduct he was certainly liable to ecclesiastical censure; but was the civil judicatory to suspend its right of investigating so grave a charge as this, and to pause till the ecclesiastical judicatory had duly deliberated whether any, and what censure was to be pronounced? Sins, however glaring, if the law does not rank them among crimes, may safely be left to the discipline of the church; but if the ecclesiastical tribunal had been found competent to interpose in cases of sedition and treason, what should have prevented it from interposing in cases of robbery and murder? It does not therefore appear to have been so unreasonable and unjust in Dr. Robertson to identify the plea advanced by Melville, with the claim which the popish clergy made to exemption from the civil jurisdiction.[1] True indeed it is that he only pleaded for the exclusive competency of the ecclesiastical court to judge in the first instance; but it is equally true that the architects of the canon law did not at once complete all the different stories of their motley edifice. His declining the jurisdiction of the civil court could however constitute no crime or misdemeanour, except in the contemplation of judges actuated with the spirit of inquisitors; and it was no small aggravation of their unjust proceedings, that they altered the terms of a sentence after it had been pronounced and recorded.

During the absence of Melville, the presbyterian form of

[1] Robertson's History of Scotland, vol. ii. p. 411. M'Crie's Life of Melville, vol. i. p. 296.

Melville. polity was again superseded, and the most arbitrary maxims of civil government were now avowed and maintained by the king and his submissive parliament. Some of the faithful ministers were committed to prison, and a considerable number sought a place of refuge in England, where they had no reason to expect the most favourable reception. The universities, being closely connected with the church, did not escape the visitations of arbitrary power. Having obtained permission to visit London, he proceeded on his journey, bearing with him instructions from the exiled nobles who were then residing at Berwick. During the ensuing month of July, he paid a visit to the universities of Oxford and Cambridge; and "he was received at these ancient seats of literature in a manner becoming his profession and merits, and expressed himself much delighted with the magnificence of the colleges, the gravity of the professors, and the courteous manners of the students." After their arrival in London, the noble exiles could not succeed in their application for the use of a separate place of worship. Balcanquall and Davidson, having preached on one or two occasions, were silenced by the bishop of the diocese; but the lieutenant of the tower invited the Scotish clergymen to preach in his chapel, which was exempted from the bishop's jurisdiction. There Melville read a Latin lecture on the book of Genesis; and we are informed that this lecture attracted a considerable auditory, and was much admired, particularly by the earl of Angus, who is said to have possessed a more cultivated mind than any other Scotish peer of that age. The government of James had become so generally unpopular, that the exiles were at length emboldened to revisit their native country; where their principal leaders were speedily joined by a military force so formidable as at once to dissolve the power and influence of the earl of Arran. After an absence of twenty months, Melville attended the banished lords on their return, and arrived in Scotland in the beginning of November 1585. He lost no time in using his best endeavours for the recovery of those liberties of which the church had recently been deprived. Some dissensions had arisen among his brethren in consequence of the defection of those who had suffered themselves to be entangled in the trammels of episcopacy; and as it was of no small importance to secure a general co-operation in the attempt to procure a repeal of the laws which had effected a change in the ecclesiastical polity, he undertook a mission to various parts of the kingdom, for the express purpose of securing this desirable union. A deputation of the ministers waited upon those noblemen who had promised to use all their influence for restoring the purity of the church; but having received evasive and unsatisfactory answers, they were constrained to make a direct application to the king, who gave them a very ungracious reception: he brought a railing accusation against them, "and made use of expressions which were not more disrespectful to them, than they were indecorous from the mouth of a king. The consequence was, that he was obliged to hear some things in reply, which were not the most grateful to his royal ears. Melville defended himself and his brethren with spirit, and hot speeches passed between him and his majesty at several interviews."

In the mean time, the affairs of the university were equally unprosperous. Thomas Buchanan, provost of Kirkhill and minister of Ceres, had begun to assist James Melville in his academical labours; but the nephew, as well as the uncle, having been compelled to quit his station, Robertson was the only professor who continued to reside in St. Mary's College. Its sole direction then devolved upon the archbishop, who himself undertook to read lectures on divinity; but as his principal topics in the chair, as well as in the pulpit, were the supremacy of the king and the preeminence of bishops, he found so little favour with his auditors, that he speedily relinquished his thankless task. He next obtained authority for converting the college into a seminary of philosophy; and Robertson, who had recommended himself by the pliancy of his conduct, was promoted to the office of principal. Finding his former station thus occupied, Melville repaired to Glasgow, where he resided with his friend Andrew Hay, rector of the university. Here he might have been reinstated in the principal's chair, which had remained vacant since the death of Smeton in 1583; but he was anxious to restore the theological seminary at St. Andrews, and to that city he accordingly returned in the ensuing month of March. The college had been placed on its former foundation, and, after an interval of two years, he now resumed his labours. The synod of Fife met at St. Andrews in the course of the following month; and in a sudden, and indeed irregular manner, the archbishop was called to an account for having exercised an unlawful office, and endeavoured to overthrow the liberties of the church of Scotland. Sentence of excommunication was pronounced against him; and, in return, having prepared a similar sentence against Melville and some of his brethren, he directed his servants to read it in the church. This censure of Adamson was not confirmed by the general assembly, but he nevertheless found himself constrained to make some abatements of his pontifical pretensions. In order to smooth the archbishop's return to his diocese, the king had recourse to the expedient of subjecting Melville to a temporary relegation. He accordingly received a written mandate to confine his residence to the north side of the river Tay; nor was it without considerable difficulty that he at length succeeded in his attempt to procure its revocation. Adamson had in the mean time been appointed to read in St. Salvator's College a Latin lecture, which all the members of the university were required to attend; but he had the mortification to find his auditory much diminished when Melville's voice was again heard in the divinity school; and this mortification appears to have been not a little encreased by the reduced numbers of the congregation when he officiated in his own church. The chapel of St. Mary's having attracted too many auditors, he procured a mandate from his majesty, prohibiting the professors of that college from preaching in the vernacular tongue. When Du Bartas, an envoy from the king of Navarre, accompanied James to St. Andrews, they came to hear a lecture from Melville, after having given him an hour's notice of their intention. He at first endeavoured to excuse himself by stating that he had already delivered his ordinary lecture, and that he was altogether unprepared for such illustrious auditors; but as his majesty would not admit of such an excuse, he pronounced an extemporary discourse, which is said to have given "satisfaction to all the hearers, except his majesty, who considered some parts of it as levelled against his favourite notions of church government." The king and the ambassador were on the following day entertained by the archbishop; who, in addition to the pontifical banquet, regaled them with an elaborate defence of prelacy and the ecclesiastical supremacy of princes. Melville, who was present, and took notes of the principal topics, had no sooner returned to his college than he ordered the bell to be rung, and conveyed to the king an intimation of his intention to deliver another lecture after an interval of two hours. Although he received two messages, partly compounded of threats and partly of blandishments, he was not to be deterred or diverted from his purpose: he declared that, even at the risk of his life, he would use his best endeavours to counteract the effects of pernicious doctrine; but so far as a sacred regard for the cause of truth would permit, he promised to be very tender of his majesty's honour. This lecture attracted a very numerous auditory, and, among the rest, the king, Du Bartas, and Adamson. With equal judgment and dexterity, he made no formal reference to the previous speech of the

Melville. archbishop, but quoted from popish books, which he then produced, all his leading positions and arguments relative to episcopacy; and all these popish doctrines he refuted with such force of reason and eloquence, that Adamson, who had previously obtained the royal permission to defend his own cause, is described as having been struck as dumb as the seat on which he had placed himself. The learned monarch was however induced to make a speech, which was interspersed with certain scholastic distinctions, and closed with an injunction to respect and obey the archbishop; an injunction which can scarcely be supposed to have fallen upon very willing ears. He afterwards deigned to partake of a collation in the college, and was regaled with "wet and dry confections, and all sorts of wine."

Of the general assembly held in June 1587, Melville was elected moderator; and he was likewise nominated one of their commissioners for attending to the proceedings in the ensuing session of parliament. On the 17th of May 1590, he was present at the coronation of the queen, and then recited a Latin poem which he had composed for the occasion, and which was immediately published.[1] His antagonist Adamson died on the 19th of February 1592, after having been deprived of his office, together with all its emoluments. The king, who was incapable of all generous feeling, left him to poverty and contempt; and such were the vicissitudes of his condition, that he was at length constrained to address a letter to Melville, which, with a profession of contrition for his previous conduct, contained the sad disclosure of his destitute situation. Melville hastened to pay him a visit, and not only procured contributions from his friends at St. Andrews, but even continued for several months to support him from his private resources. The death of this accomplished and unfortunate prelate was speedily followed by the formal restoration of presbytery. Some progress had been made during a former session, and in the month of June an act of parliament ratified the government of the church by general assemblies, provincial synods, presbyteries, and particular sessions. In the year 1593 St. Mary's College derived a considerable accession of strength from the appointment of John Johnston to a professorship of divinity. He supplied the place of Robertson; and in 1586 Patrick Melville had succeeded his cousin, the professor of oriental languages, who was now minister of Kilrenny. On the death of James Wilkie, principal of St. Leonard's College, Andrew Melville had in 1590 become rector of the university. This office, which for a series of years he continued to hold by re-election, he discharged with his usual energy. He was elected moderator of the general assembly convened in May 1594, and he bore a conspicuous part in many of the public transactions of that period. Together with his nephew James, and other two clergymen, he accompanied the king on his expedition against the popish lords, after the battle of Glenlivet; and his majesty, who had requested their attendance, found him a very faithful and able counsellor. With the view of maintaining the rights of the church, he from time to time had various audiences; and being more distinguished by intrepid sincerity than by smooth complacency, he could not often anticipate a gracious reception. In the year 1596, when the design was ascertained of recalling the popish lords from banishment, he went to Falkland with other commissioners of the general assembly, for the purpose of remonstrating against a measure which they considered as so pernicious. They were admitted to a private audience; but, from its commencement, the king testified the utmost impatience, and Melville was at length elevated to the pitch of taking his majesty by the sleeve, and calling him "God's silly vassal;" when he proceeded to address him in a strain which, as Dr. M'Crie has remarked, was "perhaps the most singular, in point of freedom, that ever saluted royal ears, or that ever proceeded from the mouth of a loyal subject, who would have spilt his blood in defence of the person and honour of his prince." While some applaud the courage of this undaunted presbyter, others may be equally disposed to condemn him as guilty of unwarrantable insolence to his sovereign. These opinions we shall not pause to discuss; but it may be proper to add, that his majesty's passion is said to have subsided while Melville thus continued to admonish him of his duty. For several years ensuing, the king made repeated attempts to regulate the church according to his own arbitrary notions; nor in any of those attempts did he meet with a more strenuous opponent than the worthy principal of St. Mary's. A royal visitation of the university took place in the year 1597, when the utmost anxiety was manifested to discover some tenable ground of accusation against an individual so obnoxious to the court. Although sufficiently aware of the situation in which he stood, he sharply rebuked the king in church for having commanded the preacher to discontinue his sermon. As the visitors were unable to find any pretext for censuring his conduct as a member of the university, they only ventured to deprive him of the office of rector: but they had recourse to another method of incapacitating him for opposing his majesty's schemes of innovation; under the pains and penalties of treason, they prohibited all professors and regents, not being pastors in the church, from sitting as members of any ecclesiastical court. Disregarding this prohibition, which proceeded from no competent authority, he did not hesitate to take his place in the provincial synod and the general assembly; but when he presented himself at Dundee as a member of assembly, James was moved with violent indignation, and commanded both him and his colleague Johnston to quit the town. In the month of November 1599, he however bore a very conspicuous part in the conference to which the king invited the principal clergy at Holyroodhouse. At every step he most strenuously contended against the restoration of episcopacy. Of the assembly held at Montrose in the year 1600, he was likewise chosen a member, but a royal mandate again prevented him from taking his seat: he however appears to have sat in the assembly convened at Burntisland in May 1601. In the course of the following year, he gave great offence in a discourse from the pulpit, by condemning the unfaithfulness and secular spirit which, as he averred, had become so common among his brethren. In order to restrain this freedom of speech, the king, by his sole authority, commanded him, under the pain of treason, to confine himself within the walls of his own college. By the intercession of the queen, his first sentence was so far relaxed as to permit him to move within a circuit of six miles from St. Andrews.

James, on succeeding to the English throne, found his hands sufficiently strengthened to complete his long-meditated changes in the Scotish church. When the parliament met at Perth in August 1606, it was clearly understood that the episcopal office was to be restored to its former privileges, and that the statute which had annexed to the crown the temporalities of the sees, was to be abolished. Melville was despatched by the presbytery of St. Andrews, with instructions to co-operate with delegates from other presbyteries in maintaining the liberties of the church; but, as may easily be supposed, they travelled on a very fruitless errand. He made an ineffectual attempt to obtain a hearing; and they could only record their opinions in the form of a strong and decided protest, which could not be received or acknowledged by the house. But a desperate expedient was at length devised for removing this scourge of episco-

[1] Στεφανισκιον, ad Scotiæ Regem, habitum in Coronatione Reginæ, 17 Maii 1590, per Andream Melvinum. Edinb. 1590, 4to.

Melville. pacy from that sphere of action, in which his opposition had been found to be so formidable. He had received a letter from the king, commanding him to repair to London before the 15th of September, in order "that his majesty might treat with him and others, his brethren, of good learning, judgment, and experience, of such things as would tend to settle the peace of the church, and to justify to the world the measures which his majesty, after such extraordinary condescension, might find it necessary to adopt for repressing the obstinate and turbulent." A similar requisition was addressed to James Melville, and to other six clergymen, namely, Scott, Carmichael, Watson, Balfour, Colt, and Wallace. They reached the English metropolis before the limited time; and soon after their arrival, they received invitations from the archbishops of Canterbury and York, but did not deem it advisable to accept them. Having been previously presented to the king, they were commanded to attend him at Hampton Court on the 22d of September; and were then informed that the important questions which he wished to propose for their consideration, related to the pretended assembly of Aberdeen, and to the best means of restoring the tranquillity of the church. They were directed to return next day, and then to deliver their opinions. When they again presented themselves, they found his majesty surrounded by the nobility of both kingdoms, and attended by the Scotish archbishops, as well as by commissioners from the conforming section of the clergy. The king was seated between the prince of Wales and the metropolitan of all England. The question relative to the assembly of Aberdeen was manifestly captious, and was proposed for the sole purpose of entangling the bold and honest presbyters in a dangerous snare. The two archbishops and their adherents had no hesitation in condemning that assembly as unlawful, factious, and turbulent; but not one of the faithful eight could be induced to utter a single word tending to implicate their brethren in any measure of blame. Melville delivered his opinion at great length, and with a degree of fire and impetuosity which astonished the English nobility and clergy. As to the other questions, relative to the pacification of the church, all the eight replied with one voice, that the only expedient for accomplishing that purpose was a free assembly. "The ministers," as Dr. M'Crie has stated, "were dismissed with unequivocal marks of approbation on the part of those who were present. The English nobility, who had not been accustomed to see the king addressed with such freedom, could not refrain from expressing their admiration at the boldness with which Melville and his associates delivered their sentiments before such an audience, at the harmony of views which appeared in all their speeches, and the readiness and pertinency of the replies which they made to every objection with which they were urged. The reports of the conference which were circulated through the city made a strong impression in their favour. It had the effect of dispelling the cloud of prejudice which had been raised against them and their brethren; and convinced the impartial that, instead of being the turbulent and unreasonable men they had been represented to be, they were only claiming their undoubted rights, and standing up for the ecclesiastical liberties of their country against the lawless encroachments of arbitrary power."

They were immediately followed to their lodgings at Kingston by Alexander Hay, one of the Scotish secretaries of state, who read to them a formal order not to return to their own country, or to approach the court without special permission. They were afterwards brought before the Scotish council, assembled at the earl of Dunbar's apartments; and various artful expedients were successively and ineffectually tried for moving their resolution or corrupting their integrity. One part of the discipline to which they were subjected was that of listening to the foolishness of preaching. The third controversial sermon which they were condemned to hear in the chapel royal, was preached by Dr. Andrews, bishop of Chichester; who from the text relative to the silver trumpets blown by the priests at the Jewish convocations, undertook to prove that the right of convocating ecclesiastical councils properly belongs to Christian emperors and kings. Did the bishops and deans, to whom they were thus constrained to listen, seriously expect presbyterian auditors to be moved, except with derision, by such mystical driveling as this? On St. Michael's day, they attended the same chapel of Hampton Court, and were not a little scandalized at the popish appearance of what is superstitiously called the altar; which displayed two closed books, two empty chalices, and two candlesticks with unlighted tapers. The prince of Vaudemont, son to the duke of Lorraine, was present, with other foreigners of distinction; and after the close of the service, he naturally enough took occasion to observe, that he saw no reason why the church of England should not unite with the church of Rome. One of his attendants was so strongly impressed with the same opinion, that he exclaimed, "Nothing but the adoration of the host is here wanting to the mass." Melville returned to his lodgings, and immediately vented his indignation in the following epigram: Melville.

Cur stant clausi Anglis libri duo regia in ara,
Lumina cæca duo, pollubra sicca duo?
Num sensum cultumque Dei tenet Anglia clausum,
Lumine cæca suo, sorde sepulta sua?
Romano an ritu dum regalem instruit aram,
Purpuream pingit relligiosa lupam?[1]

As Melville and his brethren were beset with spies, a copy of this epigram was speedily conveyed to the king, who viewed the author as guilty of a heinous offence. On the third of November he was brought before the English council at Whitehall, where he boldly avowed himself as the writer of the obnoxious verses; nor did he hesitate to express in plain prose his feelings of grief and indignation at seeing the superstitions of popery retained in a church professing to be reformed. He however added that he had not given any person a copy of the epigram; and that if he had committed an offence, he was not amenable to the English council, especially when his sovereign was not present. The archbishop of Canterbury then began to expatiate on the aggravated nature of his offence, which he described as coming within the definition of treason. "My lords," he indignantly exclaimed, "Andrew Melville was never a traitor; but there was one Richard Bancroft (let him be sought for), who, during the life of the late queen, wrote a treatise against his majesty's title to the crown of England, and here is the book." Bancroft, who was totally unprepared for such an act of retaliation, sat in mute astonishment, while the Scotish presbyter proceeded to accuse him of profaning the sabbath, and of silencing and imprisoning faithful preachers of the gospel for scrupling to conform to the vain and superstitious ceremonies of an antichristian hierarchy. He gradually advanced so near this pontiff as to shake his lawn sleeves; and, calling them Romish rags, he thus continued to address him: "If you are the author of the book called 'England Scottizing for Geneva Discipline,' then I regard you as the capital enemy of all the reformed churches in Europe, and as such I will profess myself an enemy to you and your proceedings, to the effusion of the last drop of my blood; and it grieves me that such a man should have his majesty's ear, and sit so high in this honourable council."

[1] Melvini Musæ, p. 24. *Anno* 1620, 4to.

Melville. Dr Barlow, bishop of Lincoln, having at length ventured to interpose, was subjected to the same unceremonious treatment; nor did his sermon on the beauties of episcopacy, with which he had recently edified the presbyterian brethren, escape severe animadversion. Melville was finally admonished by the lord chancellor Ellesmere to add modesty and discretion to his learning and years; and was moreover informed that he had been found guilty of *scandalum magnatum*, and was to be committed to the custody of the dean of St. Paul's till the king should signify his pleasure as to his further punishment. In the custody of Dr. Overall he remained till the 9th of March 1607, when he received from the council an order to remove to the bishop of Winchester's residence in London: but as he was not attended by the messenger who delivered this order, he paid a visit of several weeks to his brethren. On the 26th of April he was again summoned before the council. The king of Great Britain, France, and Ireland had recourse to the expedient of stationing himself in a closet where he could hear without being seen; and he received the appropriate reward of hearing himself mentioned with the utmost freedom of speech by the most undaunted of his subjects. The poor archbishop, the earls of Salisbury and Northampton, with the lord treasurer, were all exposed to the reprehensions of a man who spared none of their vices, public or private. By a most inquisitorial and iniquitous sentence, worthy of Rome or Toledo, he was committed as a prisoner to the Tower. His nephew, who had written no epigram on the superstitions of the church, was commanded to fix his residence at Newcastle upon Tyne, and not to move beyond a distance of ten miles from that town.[1] Their brethren were permitted to return to Scotland, but were each of them restricted to particular limits. Such at that period was the spirit of the English government, and such were the unhallowed means of upholding a protestant church. The spirit of popery is not always confined to the popedom.

Melville's office was soon afterwards declared vacant, and Robert Howie, a man of respectable attainments in learning, succeeded him as principal of St. Mary's College. For the space of about ten months, the prisoner was subjected to the most rigorous treatment: no person was allowed to visit him, he was not permitted to retain a servant, and was even denied the use of pen and ink. But his manly spirit was still unsubdued, and he endeavoured to amuse his solitary hours by composing Latin verses, which with the tongue of his shoe-buckle he engraved on the walls of his prison-house. From these unnecessary restraints he was at length released by the intercession of some of his friends at court, and particularly of Sir James Semple, who was himself a man of learning, and an able supporter of the presbyterian polity. Before the close of the year 1607, the protestants of Rochelle endeavoured to obtain his services, as professor of divinity in their college, but James could not yet be induced to open the doors of his prison. After another interval of twelve months, he was moved by the suggestion of some person of rank to address the king in Latin verse, but in this case verse was incapable of soothing the ear of the royal poet. By the advice of Archbishop Spotswood, whose sincerity he afterwards found strong reasons to distrust, he addressed to the privy council a letter in which, without compromising his own dignity of character, he endeavoured to persuade them that an imprisonment of two years was a sufficient punishment for any offence which he might have committed. But these unjust judges likewise turned a deaf ear to his supplication, and he was doomed to remain a prisoner for an additional period of two years; at the expiration of which, he was released at the intercession of the duke of Bouillon, who invited him to fill a professor's chair in the protestant university of Sedan. Notwithstanding his tedious confinement, he had enjoyed a large measure of good health; but the vigour of his constitution was at length impaired, and having been seized with a fever, he obtained permission to leave the Tower for a few days, but under the condition of not removing beyond the distance of ten miles from London. His health returned, and it became necessary to prepare for a voyage, which, it may easily be conceived, he undertook with some degree of reluctance. He was now in the sixty-sixth year of his age, and had long filled an honourable and conspicuous station in his native land, to which he felt that strong attachment which his countrymen so generally feel. But the wrath of kings and bishops is sometimes not easily appeased; and this aged, learned, and conscientious divine was compelled to relinquish the hope of returning to the land of his nativity, and after having so far declined into the vale of years, to proceed in search of a new country. Melville.

Ἅπας μὲν ἀὴρ ἀετῷ περάσιμος,
Ἅπασα δὲ χθὼν ἀνδρὶ γενναίῳ πατρίς.

On the 19th of April 1611, he embarked for France; and having spent a few days at Rouen and Paris, he arrived at Sedan in the course of the ensuing month. In this university he was associated with several of his countrymen: the office of principal was held by Walter Donaldson, LL.D. who was likewise professor of natural and moral philosophy; and another professor of philosophy was John Smith. Melville was installed as a professor of divinity, and to him was assigned the department of biblical literature, while his colleague Tilenus taught systematic theology. Another member of the theological faculty was Jacques Cappel, who taught the Hebrew language with no small reputation. Daniel Tilenus, a native of Silesia, was morose in his temperament, and did not prove a very desirable associate. After having written against the opinions of Arminius, he became an avowed convert to them; and being refuted by Melville in his academical lectures, he quitted the university of Sedan, and was afterwards conspicuous as a bitter opponent of the opinions of Calvin. Our learned countryman still retained a large portion of mental vivacity, nor were his bodily senses materially impaired: at the age of sixty-eight, he could read the smallest Hebrew characters without the aid of spectacles. He was however exposed to occasional visitations of colic, gout, and gravel; nor did he cease to cherish some lingering, though faint, hope of being permitted to deposit his bones in the land of his fathers. His mortal career was however terminated at Sedan in the year 1622, when he had attained the age of seventy-seven.

Melville was small in stature, and was alike conspicuous for his vivacity of body and mind. His elasticity of spirit, which he appears to have retained till the last years of his life, was accompanied with a warm and impetuous temperament, which however was free from all personal malignity. Whenever he engaged in any undertaking that he deemed important, he displayed a degree of ardour and zeal which could not fail to excite the surprize of persons more cool, as well as more obtuse than himself. His zeal was pure and disinterested, nor did he hesitate to endanger his liberty or life in maintaining those principles of civil and religious

[1] James Melville was afterwards permitted to reside at Berwick, where he died on the 19th of January 1614, in the fifty-ninth year of his age, and the eighth of his banishment. He was twice married, and left several children. He appears to have been an upright and disinterested man: his zeal, less fiery than that of his uncle, was equally uniform and consistent, nor did the offer of a bishopric shake his attachment to presbytery. His talents were much inferior to those of his uncle. He is the author of various works in the Latin and Scotish languages. His Diary, recently printed for the Bannatyne Club, contains much curious information relative to the ecclesiastical and literary history of that age.

Melville. freedom to which his heart and soul were so entirely devoted. From his early youth, he was distinguished by fervid and consistent piety. He was a man of the most unblemished integrity, nor did his enemies, who were sufficiently numerous, venture to charge him with sordid or selfish motives of conduct: their accusations chiefly relate to his want of personal reverence for the king, and to his want of veneration for bishops, with all their Romish remnants; and it must indeed be admitted that, although possessed of the most genuine loyalty, he treated his sovereign with very little ceremony, and that he regarded the English and the Romish prelacy as essentially partaking of the same spirit. As to his personal treatment of the king, it is without hesitation to be conceded that the reverence which may not be due to the individual is at least due to the office. The other question, as to the genuine character and inevitable tendency of a lordly prelacy, we shall here suffer to rest on its own merits. In private life he appears to have been very amiable and affectionate: if his indignation was easily roused, it was also easily appeased; and he was free from that arrogance by which men of intellectual superiority have sometimes rendered themselves more feared than respected. Melville was unquestionably possessed of very uncommon talents, and he had acquired an ample and varied store of erudition. His proficiency, not merely in classical, but even in oriental literature, was not denied by such of his contemporaries as were least disposed to bestow commendation which he did not undeniably merit. For the depth as well as the extent of his theological learning, he was generally admired by those who had the best opportunities of forming a correct judgment. We have already observed that he had devoted considerable attention to the study of law, and some of his enemies represented him as too much addicted to the study of politics, while his friends were equally persuaded that all his talents and all his energies were uniformly directed to the most beneficial purposes. Such was his indifference to literary reputation that although so capable of writing in prose or verse, he committed very few works to the press.[1] During his long and active life, and under all its vicissitudes, he continued to feel the attractions of the Roman Muse. Nature had bestowed upon him the fancy and feeling of a poet, and his verses frequently display uncommon felicity and elegance. (x.)

Melville, Sir James, whose name is familiarly known to the readers of Scotish history, was born in the year 1535. He was the third son of Sir John Melville of Raith in Fifeshire, by his wife Helen, the eldest daughter of Sir Alexander Napier of Merchiston. At an early period the father declared his adherence to the reformed doctrines, and thus incurred the unrelenting hatred of an unholy priesthood. He was accused of heresy by Archbishop Beaton, but upon this occasion was protected by the interposition of the king. When the war with England ensued during the minority of the queen, all intercourse with that country was prohibited under heavy penalties. His eldest son having been sent thither for his education, Sir John addressed to him a letter which was intercepted, and which, although so harmless in its tendency, was converted by Archbishop Hamilton into the instrument of his destruction: he was arrested at the instigation of this prelate, and having been sent under a strong guard to Stirling, was convicted of high treason, and brought to the scaffold. Not satisfied with this atrocious act, the archbishop found means to obtain possession of his estate, and thus to reduce his widow and children to a state of penury. "But," as we are informed, "the Almighty ordered matters so, that all the younger children were better provided for than they could have been by their father if he had been alive, as Sir John himself had foretold his lady to comfort her."[2] At the period of this judicial murder, his third son had attained the age of fourteen. Jean de Monluc, bishop of Valence, had visited the Scotish court in the capacity of an ambassador; and on his return to his own country, the queen regent took that opportunity of sending young Melville to be placed in her daughter's service as a page of honour. The bishop did not however proceed directly to France: he had received instructions to visit Ireland, for the purpose of communicating with O'Neill, O'Docherty, and other disaffected chieftains, who had offered to transfer their allegiance to the French king. He embarked at Irvine in the month of January 1550, and, after a tedious and dangerous passage, at length reached Lochfoyle. O'Docherty conducted Monluc with his attendants to his own residence, a large and dark tower, where, as it was now the season of Lent, they were regaled with such cold cheer as herrings and biscuit. The bishop having discovered a too amorous partiality for the chieftain's daughter, two English friars, who were living in exile, devised a method for saving the honour of the O'Dochertys, and ministering to the wants of so exemplary a prelate.[3] The damsel herself, who had shunned his addresses, viewed Melville with more favourable eyes: she sought him wherever he was to be found, and having brought a priest who could speak English, she offered to marry him, and to accompany him wherever he pleased; but he thought it expedient to decline the honour thus intended for him, on the plea that he was too young, and "had no rents." After remaining for several weeks in Ireland, they returned to Scotland, and having again embarked, they sailed from Dumbarton, and landed at a port in Bretagne. Monluc posted to Paris, and left the Scotish page to follow at a more leisurely pace. Having met with some adventures by the way, he reached his place of destination in the month of April. The bishop was soon afterwards despatched to Rome, and left him at Paris, to learn to play on the lute, and to write French; and to these acquirements he added the elements of mathematics. Before he was presented to the queen, a curious incident brought him under the notice of the great constable Montmorenci, who must evidently have been much pleased with his appearance, for he instantly proposed to receive him into his own service. Having previously obtained the bishop's consent, he accordingly entered into this service in May 1553.

Melville.

War was now raging between the king of France and the emperor of Germany, and Melville was speedily called to attend the constable in his campaigns in France and

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[1] His works have been enumerated by Dr. M'Crie, Life of Melville, vol. ii. p. 510. To this accurate list we have only to add an unpublished "Commentarius in divinam Pauli Epistolam ad Romanos, auctore Andrea Melvino Scoto." The manuscript, a small quarto of 121 leaves, transcribed with much elegance, is in the possession of Mr. David Laing, to whom we are indebted for the use of it, as well as for many other favours of a similar kind.

[2] Wood's Peerage of Scotland, vol. ii. p. 112.

[3] "The said freres persaving the bischop to mak a compt of Odocartis dochter, wha fled him continowally, they brocht to him a woman that spak Englis to ly with him; whilk harlet being keped quyetly in his chamber, fand a little glass within a kaice standing in a window, for the coffers wer all wet be the sea wallis that fell in the schip during the storm. Bot sche beleuit it had bene ordonit to eat, because it had ane odoriphant smell, therefore sche lickit it clean out; quhilk put the bischop in sic a rage that he cryed out for impatience, and discouerit his harlettrie and his colair in sic sort as the freris fled and the woman folowed. Bot the Yrisch men and his auen saruandis leuch at the matter, for it was a phioll of the only maist precious balm that grew in Egipt, whilk Solyman the Gret Turc had geuen in a present to the said bischop efter he had bene twa yeares ambassadour for the K. of France in Turky, and was esteamed worth twa thowsand crownis." (Melville's Memoirs, p. 10.)

Melville. Flanders. The kindness of his patron procured him a pension from the king in the year 1554. In 1557 he bore arms at the battle of St. Quentin, where the constable's army was totally defeated, and he was himself wounded and taken prisoner. Melville was wounded in the head by the stroke of a mace, and as he was unhorsed and lost his helmet, he was exposed to no small jeopardy; but his servant remounted him upon a Scotish gelding, which carried him beyond the reach of his assailants. Having proceeded to La Ferre, he there met his friend Henry Killigrew, who held his horse till he went into a barber's shop to have his wound dressed. He attended the constable during his captivity; from which he was delivered by the treaty of Cateau-Cambresis, concluded in the year 1559. In the course of the same year, the king, at Montmorenci's suggestion, sent him on a secret mission to Scotland, where, under the pretext of paying a visit to his relations, he was instructed to use his best endeavours for ascertaining the real views of the prior of St. Andrews and his adherents. Having travelled through England, he found the queen regent residing in the old tower of Falkland, waiting the issue of an expected engagement between her forces and those raised by the lords of the congregation. He easily ascertained that there was no reason for suspecting the prior of a design to usurp the crown. A melancholy change of affairs awaited his return to France: the constable had the singular infelicity to kill his sovereign Henry the Second in a tournament, and had been commanded to withdraw from court; so that he no longer retained the same power of rewarding or advancing his dependants. This circumstance he regretted with tears in his eyes. Melville, although received with the greatest kindness, judged it expedient to try his fortune in another country, and he now directed his views towards Germany. To the Elector Palatine, he was furnished with letters of recommendation by his patron, as well as by another nobleman. He experienced a gracious reception, and made such progress in the elector's favour, that in 1560, on the death of Francis the Second, he was charged with a message of condolence to the court of France. When he had executed this commission, the queen mother dismissed him with many thanks, and with a fair reward amounting to the value of a thousand crowns. His residence in Germany afforded him an opportunity of learning the language of that country; an acquisition which he must have found of some advantage to a diplomatist. In company with the elector's second son Casimir, he visited France during the following year; and he there made a tender of his services to Queen Mary, who was on the eve of returning to Scotland. She received him very graciously, and urged him, "when he wes to retire him out of Germany, to com hame and serue hir Maieste, with frendly and fauorable offers."

The cardinal of Lorraine had projected a marriage between Mary and the archduke Charles of Austria, the youngest son of the emperor Ferdinand. In 1562 Melville received a letter from secretary Maitland, instructing him, by the queen's command, to procure and transmit particular information respecting the person, character, religion, and revenues of this prince. The kindness of his master the elector speedily enabled him to execute his commission. With the emperor's eldest son Maximilian, then king of the Romans, he had various interviews; and was at no loss to discover that he had no inclination to promote his brother's elevation to a throne. The king offered to retain him in his own service; but he had now formed the resolution of returning to his native country, after he had extended his travels to Italy. He accordingly proceeded to Venice and Rome, and, after an interval of about two months, returned through Switzerland to Heidelberg. The elector soon afterwards employed him in a diplomatic mission to Paris; where he found the constable again frequenting the court, but without having recovered the influence which he once possessed. It is another proof of Melville's courtier-like address, that the queen mother offered to make him a gentleman of the king's chamber, "prouydit with ane honorable pension, and to be aduancit till offices and honnours as geue he wer a Frencheman born; and that sche wald employ him not only in Germany, bot also in England and Flanders." But about this crisis he received communications from Moray and Maitland, requiring him, in the name of their royal mistress, to return home for the purpose of being employed in some affairs of consequence. Having once more repaired to Heidelberg, he took leave of the Elector Palatine; who finally entrusted him with a commission to the queen of England, partly relating to an alliance with the protestant princes of Germany, and partly to a scheme of offering her the hand of prince Casimir. He now proceeded to London, and, after having paid his respects to Elizabeth, directed his steps towards his native country. On the 5th of May 1564 he presented himself to Mary at Perth, and had every reason to be satisfied with the mode of his reception; but the general aspect of affairs in Scotland was less promising than he had been led to anticipate. He was however induced to engage in her service, and he received a pension of a thousand marks. She likewise offered to bestow upon him the demesne of Auchtermuchty; but as it was so contiguous to the royal palace of Falkland, he expressed his unwillingness to avail himself of her liberality, when another individual who was not so scrupulous, made a successful application for the valuable gift which he had declined. Melville.

After an interval of a few months, Melville was entrusted with an embassy to the queen of England. Of his proceedings on this occasion, he has given a circumstantial and characteristic account, in which the vanity, coquetry, and insincerity of Elizabeth are very prominently displayed. On my return to Edinburgh, he states, "efter that hir Maieste had vnderstand at gret lenth all my handling and proceadingis in England, sche inquyrit whither I thocht that quen menit trewly towardis hir asweill inwartly in hir hart, as sche apperit to do outwardly be hir speach. I said, in my jugement, that ther was nather plain dealing nor vprycht meanyng, bot gret dissimulation, emulation, and fear that hir princely qualites suld ouer schone, chaise hir out, and displace hir from the kingdome; as having alredy hendrit hir mariage with the Archeduc Charles of Austria, and now offering vnto hir my L. of Leycester, whom sche wald be laith as then to want." He continued his attendance at court after the queen's marriage with Darnley, and must sometimes have had a difficult and delicate part to perform. On the birth of a prince, 19 June 1566, he was instantly despatched to convey the intelligence to Elizabeth. He found her at Greenwich; "wher hir Maieste was in gret merines, and dancing efter supper, but sa schone as the secretary Cicill roundit the newes in hir ear of the prince birth, all merines was layed asyd for that nycht; euery ane that wer present marueling what mycht moue sa sodane a chengement; for the quen sat down with hir hand vpon hir haffet, and boursting out to some of hir ladies, how that the quen of Scotlandis was leichter of a faire sonne, and that sche was bot a barren stok." During the following year, when Mary was intercepted by the earl of Bothwell, he was among her other attendants, and along with her was conducted to Dunbar castle, but was only detained for a single day. He was seized by Captain Blackader, who "allegit that it was with the quenis awen consent." From this period he did not so regularly attend the court, but he happened to be present at her scandalous nuptials with the murdeter of her former husband. During the civil commotions which succeeded, he did not remain entirely inactive: he appears to have pursued a prudent and cautious tenor of conduct, and to have abstained from involving himself too deeply with either of the adverse factions. He

Melville. had adhered to the queen till she was committed to Lochleven castle; but he undertook to be the bearer of a message from the lords who entertained the design of crowning the infant prince, to the chief supporters of the mother's cause, who were then convened at Hamilton; and, about the same crisis, when the earl of Moray returned from France to assume the office of regent, he was delegated by the same party to meet him at Berwick. To the next regent, the earl of Lennox, he of his own accord presented himself at the same place; and, under his administration, as well as that of his successors Mar and Morton, he had some concern in public affairs. After the king received the reins of government into his own hands, he was appointed a gentleman of the bedchamber, and a member of the privy council. In 1582 he was nominated, along with Lord Newbattle, David Macgill, and John Sharp, to hold in Edinburgh justice eyres for the county of Linlithgow. The enterprize commonly described as the Raid of Ruthven speedily followed. While the king still continued under restraint, he sent a message to Melville, requiring his attendance at Falkland. This summons he immediately obeyed, and, according to his own narrative, he had a principal share in effecting his Majesty's liberation. He was not however acceptable to James's unworthy favourite the earl of Arran, through whose influence his name was in 1584 expunged from the list of privy councillors. He did not entirely lose the king's favour, but was soon afterwards consulted on various occasions. When the ambassadors arrived from Denmark in 1585, he was appointed to "entertain them, and bear them company." With some part of the treatment which they experienced at the Scotish court, these ambassadors had no great reason to be satisfied; and it required all Melville's talents and address to prevent them from returning to their own country in a very vindictive mood. When the king afterwards proposed to send him as one of his ambassadors to Denmark, he thought it advisable to decline this honour. On the establishment of the queen's household in the year 1590, James placed him there as a councillor, and in that capacity he continued for several years; "keping sometymes the consaill dayes, and sometymes assisting vpon the chekker, when ther Maiesteis wer togither, bot when they wer sindrie, he awated only vpon the quen." At the baptism of prince Henry, he was called to assist in the splendid ceremonial; he was stationed behind the queen, and aided her in receiving the presents offered by the ambassadors of different states.

When the king succeeded to the crown of England, as we are informed by Melville's grandson, he "would gladly have taken him along with him thither, offering him considerable advancements there: but being now stricken in years, and desirous to retreat from the troubles of the world, to spend the remainder of his days in contemplation, [he] begged his Majesties permission thereto. However, after the king's going for London, he found himself in duty engag'd once to wait upon his Majesty in that kingdom, and accordingly went thither, and was graciously received; and having attended there some weeks, humbly giving his Majesty his best advice, no court allurements (whereof he had great store) could prevail with him to alter his former resolutions of privacy." He died on the 13th of November 1617,[1] at the mature age of eighty-two. By his wife, Christian, the daughter of David Boswell of Balmuto, he left several children. The estate of Hallhill in Fifeshire descended to his son James. His daughter Elizabeth was married to John Lord Colville of Culross; and she is well known as the pious and ingenious author of a poem commonly described as Lady Culross's Dream. Margaret, another daughter, became the second wife of Sir John Scott of Scotstarvet. From the eldest brother of Sir James Melville is descended the noble family of Leven and Melville.

Melville ‖ Memel.

Melville employed some portion of his declining age in writing Memoirs of his public life; and the work was published by his grandson, George Scott of Pitlochie, sixty-six years after the death of the author. "The Memoires of Sir James Melvil of Hal-hill; containing an impartial Account of the most remarkable Affairs of State during the last Age, not mention'd by other historians, more particularly relating to the Kingdoms of England and Scotland, under the Reigns of Queen Elizabeth, Mary Queen of Scots, and King James; in all which transactions the author was personally and publickly concern'd. Now published from the original manuscript, by George Scott, Gent." London, 1683, fol. Edinburgh, 1735, 8vo. Glasgow, 1751, 12mo. A French translation, in 2 vols. 8vo., appeared at the Hague in 1694, was reprinted at Lyon in 1695, and at Amsterdam in 1704. A new version, or the same remodelled, was published in 1745 in 3 vols. 8vo., bearing the imprint, "à Edimbourg, chez Barrows et Young." "The work," as Mr. Thomson states, "was evidently printed abroad. The additions, which fill the third volume, consist of letters, written chiefly by Queen Mary, selected from various printed works." These various editions of the Memoirs afford sufficient evidence that the book had excited no small degree of interest on the continent, as well as in our own country. Bishop Burnet, to whom it had been communicated in manuscript, described it as "one of the best and perfectest pieces of that nature that he had seen." It was originally published in that unfaithful and injudicious manner, in which the editors of a former age were too apt to suppose themselves entitled to exercise their functions: so violent an attempt was made to reduce the phraseology to the English standard, and so many interpolations were admitted, that in not a few instances it is extremely difficult to recognize the general texture of Melville's own narrative. The fidelity of the editor was therefore liable to strong suspicion, which was naturally augmented by the consideration that no early copy of the Memoirs could be traced in any public or private library. But a manuscript, apparently in the handwriting of the author, was at length discovered in the collection bequeathed to Mr. Rose by the Earl of Marchmont, and since inherited by Sir George H. Rose. From this manuscript the work has recently been printed for the Bannatyne Club, under the able superintendence of Thomas Thomson, Esq. "Memoirs of his own Life by Sir James Melville of Halhill. M.D.XLIX.—M.D.XCIII. From the original manuscript." Edinb. 1827, 4to. Melville's Memoirs, in this authentic form, are a most valuable accession to the stock of original materials for Scotish history.

MELVILLE BAY, a harbour on the north coast of New Holland, at the west entrance into the Gulf of Carpentaria, visited by Captain Flinders, and found to be the best harbour in the gulf. Long. of Point Dundas, at the entrance of the bay, 136. 41. 40. E. Lat. 12. 13. 0. S. There is an island of the same name at the entrance into this gulf, on the west side, and about five miles long. Long. 136. 52. E. Lat. 12. 8. S.

MEMEL, a city of the province of East Prussia, in the government of Königsberg. It is the capital of a circle of the same name, which extends over 621 square miles, and contains, besides the city, five parishes, with 33,600 inhabitants. The city is situated on a peninsula at the mouth of the Curish Haff, on the river Dange, which empties itself into the Baltic Sea. The harbour is partly in the river and partly in an extensive basin, and both are capable of receiving more than 700 large ships, such as are required for the timber trade, which is the principal commerce of the

[1] Wood's Peerage, vol. ii. p. 112. Melville has stated that he was "14 years past" when he was committed to the charge of Monluc; an event which happened in the year 1549. He must therefore have been born in 1535, and have lived to the age of eighty-two.

Memmingen ‖ Memoirs.

place, and for which it is advantageously situated. The city is strongly fortified, and forms the chief defence of the frontier towards Russia. It is divided into the old city, the Fredrick's city, and the suburbs. It has a citadel, two Lutheran churches, one reformed, and one Catholic, an hospital and school of industry, and 680 houses, mostly large, with about 10,000 inhabitants. Besides the trade in timber already noticed, much corn, flax, hemp, and potash is exported. There are some linen and several leather manufactories, several breweries and distilleries, and many mills for sawing timber. The chief exports are to England and Holland, whence are derived the supplies of sugar and other colonial articles. Lat. 55. 42. 15. N. Long. 21. 1. 0. E.

MEMMINGEN, a city of Bavaria, in the circle of the Upper Danube, and the capital of the courts of law of the several bailiwicks. It is situated in a pleasant district, on the river Ach, and contains three Lutheran and three Catholic churches, 1150 houses, and 6640 inhabitants. It is an old town, surrounded with walls, and some large antique public buildings. It has become a place of considerable manufacturing industry in linen and cotton goods, and has some trade in corn, hops, wool, wine, and ironmongery. Lat. 47. 59. 40. N. Long. 10. 5. 2. E.

MEMNON, a name given by the Greeks to various personages; as to a fabulous king of Ethiopia, who is said to have gone to the assistance of King Priam, during the Trojan war, with a body of ten thousand men; and also to several kings of Egypt, whose era and dynasty are involved in impenetrable obscurity. The word, in fact, seems to be a distinctive or qualifying epithet, rather than a proper name; an abbreviated form of MEI-AMUN, "*beloved of Ammon*," which the Greeks, who were unacquainted with the Egyptian language, naturally enough converted into MEMNON; and hence it may have been applied to any or every king who was conceived to be, in an especial manner, favoured or protected by Ammon, the supreme head of the Egyptian Pantheon. But there is one Pharaoh, in particular, called Memnon by the Greek writers, in honour of whom the Egyptians are supposed to have erected that celebrated statue, which is alleged to have possessed the wonderful property of uttering a sound every morning at sunrise, resembling that which is produced by the sudden breaking of the string of a harp from excessive tension. This subject is discussed at length in the article EGYPT, (vol. viij, p. 536), to which, accordingly, the reader is referred. It is sufficient to observe here that the idea of a colossal statue of hard reddish sandstone being in any way affected by the morning rays of the sun, is too absurd to deserve serious refutation. But as the ancient Greek writers, and the numerous inscriptions upon the legs and feet of the vocal colossus, all bear testimony to the fact, that some sound of the kind or description mentioned was given out by the statue; and as Strabo the geographer distinctly states that he had himself heard it, though he could not say with certainty whence the sound proceeded; the most probable hypothesis is, that it was produced by artificial means, as by striking a smart blow on some sonorous material concealed within the colossus.

There were other persons of the name of Memnon, besides the Egyptian king; as, first, a general of Darius, who, when Alexander invaded Asia, distinguished himself alike by his sagacity in council and his gallant bearing in the field; secondly, a governor of Thrace appointed by Alexander, on account of his tried fidelity and experience; and, thirdly, the author of a history of Heraclea in Pontus, written in the age of Augustus. (A.)

MEMOIRS, in literature, a species of history, written by persons who had some share in the transactions they relate, and answering to what the Romans called *Commentarii*. The journals of the proceedings of a literary society, or a collection of the matters therein transacted, are likewise called *Memoirs*.

Memory ‖ Menancabow.

MEMORY, a faculty of the mind, which presents to us ideas or notions of what is past, accompanied with a persuasion that the things themselves were formerly real and present. What we distinctly remember to have perceived, we believe as firmly to have happened, as that which is now present to our senses. See METAPHYSICS.

MEMPHIS, the second capital of Egypt, situated on the western bank of the Nile, above the Delta, was scarcely inferior to Thebes in the extent and magnificence of its sacred edifices, and even in the time of Strabo was second only to Alexandria in point of size and population. The site and name of this ancient city were well known in the twelfth and thirteenth centuries, as appears from the account of it given by El-Idrisi. By the Arabian geographer it is mentioned under the name of *Menph* or *Memph*, which is merely an abbreviation of the Egyptian name of *Memphi* or *Memphe*; the hieroglyphic name, being MA-M-PHTHA, the *sacred place*, or *temple* of *Phtha* or Vulcan. Before the time of the Ptolemies, the place had apparently assumed the synonymous appellation of PANOUPH or PANOUPHIS, the NOPH of the Hebrews, which signifies the temple of the good god. One of the most remarkable structures in Memphis was the temple dedicated to Phtha, the patron divinity of the place; of this, however, nothing but the débris remains. The same fate has overtaken the temple of Osiris, in which the sacred bull Apis was kept; another consecrated to Hâthor, or Venus; and a third dedicated to Serapis, all adjoining to the great temple of Phtha. Of the wonderful Labyrinth, which, according to Herodotus, exceeded all description, not so much as a vestige or trace remains. Indeed, so rapidly has the work of destruction proceeded, especially since the fourteenth century, that few points have been more debated in modern times than the site of this celebrated city; and, excepting its pyramids, and the great plain of mummies which attest the vicinity of the spot whereon stood the second capital of Egypt, it might almost be said of it, *Etiam periêre ruinæ*. But its distance from the pyramids and the apex of the Delta, two fixed points, having been clearly pointed out by Strabo, Pococke and Bruce were thereby led to fix upon the neighbourhood of Mokhnan and Monyet-Rahineh, two villages on the left or western bank of the Nile, as the ground upon which Memphis had once stood; and the opinion of these travellers was completely confirmed by the French during their military occupation of Egypt. In fact, after the successive generations of Greeks, Romans, and Arabians had plundered Memphis, in the wantonness of victory, or for the purpose of transferring its monuments to Alexandria or Cairo, we may well wonder that, exclusively of those eternal structures the pyramids, enough should still remain to enable us to fix the probable site of the second capital of the Pharaohs. (See the article EGYPT, vol. viij. p. 546.) (A)

MENANCABOW. This state or empire is situated in the centre of the island of Sumatra, immediately under the equinoctial line. Its dominion was formerly very extensive, comprehending the whole island. When the island of Sumatra was first visited by Europeans, this state was on the decline. In more modern times it was included between the river Palemburg and that of Siak, on the eastern side of the island; and on the western side, between those of Manjuta (now Indrapur) and Singkel, where it borders on the independent country of the Battas. The present seat of the government is inland of the settlement of Padang, at the back of a mountainous district. The country is described as a large plain, surrounded with hills producing much gold, and as clear of wood and comparatively well cultivated; the people being far more advanced in the arts than any of the other natives in Sumatra. They manufacture gold and silver filagree, and have manufactured from the earliest times arms for their own use, and for exportation to the northern parts of the island. They have other weapons,

Menander. namely, swords and spears, a stiletto, chiefly used for assassination, and the fatal *kris*, a well known species of dagger in eastern countries. The government is founded upon feudal principles, like that of most other eastern states. The sultan is despotic, though he is controled by the aristocracy; and the people are slaves.

MENANDER, a celebrated comic poet of Athens, was the son of Diopithes and Hegisistrate, and belonged to the demus of Cephissia. His family was of considerable eminence at Athens, as we find his father commanding the Athenian forces on the Hellespont in the war with Philip of Macedonia, B.C. 342. (Dionys. *Dinarch.* p. 666.) Menander was born B.C. 342, the year before the birth of Epicurus, and he died B.C. 291. At the time that Menander was born, Demosthenes was forty years of age, and Æschines forty-seven. Of his private history the few facts that have been transmitted are of little moment. He was the nephew of the poet Alexis to whom he was indebted for his education; (Suid. *Proleg. Aristoph.* p. xxx.) though he also studied under the philosopher Theophrastus, (Diog. Laert. *Theophr.*) As early as his twenty-first year he exhibited his first play, entitled Ὀργὴ, and gained a prize. (Aristoph. l. c. Euseb. *Ol.* 114. 4.) Authors are not agreed as to the number of plays which he composed; some say 109, others 108, (Suid.) and Apollodorus 105. (Gell.) Athenæus mentions the titles of fifty plays. Menander wrote also letters addressed to king Ptolemæus Soter, (306–283 B.C.), and several orations in prose. Only eight of his plays were thought worthy by the Athenian judges of receiving the crown of victory; but as Euripides was even still more unsuccessful we must not consider this as a decisive proof of their inferiority. So much indeed did the poet feel the injustice of this treatment and the unworthiness of some of those who were the successful competitors, that on meeting Philemon he inquired of him whether he did not blush when he heard himself declared victor. (*Gell.* xvii. 4.) Menander was accused by the ancients of plagiarism, and the grammarian Cratinus composed a work in six books on the thefts of Menander, but this accusation appears to have been dictated by envy. Menander is said to have been a great admirer of the female sex; hence Ovid (*Trist.* xi. 370.) has remarked that there is no comedy of Menander in which love is not introduced, and yet that the manners are sufficiently pure to allow a mother to place these dramas in the hands of her daughter. On this point we may remark that the manners of the Greeks differed much from those of the present day, and we can have no doubt that the subjects of many of them were such as would exclude them from our drawing-rooms. The titles of three of his plays, Thais, Glycerium, and Nannion, shew that they treated of ladies of not the most reputable characters. It is well known that Terence carried his imitation of Menander so far as sometimes merely to translate his plays, and hence Cæsar calls him Dimidiate Menander. *(Epigr. ap. Donat. Vit. Terent.)* It is much to be regretted that the whole of his works have perished, with the exception of a few fragments which have been preserved by different grammarians and philosophers. Menander was the founder of the new comedy, in which vices were censured without reference to particular facts, and in which the action of the play was not impeded by the presence and declamation of a chorus. It must have differed little from a modern comedy except in being somewhat less pure in manners. Plutarch has drawn a parallel between Menander and Aristophanes, in which he thus expresses his opinion of the former: "Menander can adapt his style so as to suit any character; he never loses sight of nature, is always equal to himself, and always different, according as the subject requires a change of manner; like to a limpid stream which, flowing between unequal banks, assumes all its forms without losing any of its purity. He is made to be read, represented, learned by heart, to please in every place, and every time." Quintilian says, "He has delineated the picture of human life most accurately; his invention is fruitful, his eloquence powerful, his characters, passions, and manners, proper and natural." (x. 1.) It is said that Menander was drowned whilst he was bathing in the Piræus at Athens; (*Schol. Ovid.* 593.) and the Athenians erected a tomb to his honour not far from that of Euripides. (Pausan. i. 6.) The fragments of Menander have been collected in the *Poëtæ Græci Minores*, Cambridge, 1652. The most complete edition is that by Leclerc, Amsterdam, 1709. (See Menandri et Philemonii *Reliquiæ*, edited by Meineke, Berlin, 1823.)

Menandrians ‖ Mendeli.

MENANDRIANS, the most ancient branch of the Gnostics, who were so called from Menander their chief, said by some, though without sufficient foundation, to have been a disciple of Simon Magus, and himself a reputed magician. He taught, that no person could be saved, unless he were baptised in his name; and that he conferred a peculiar sort of baptism, which would render those who received it immortal in the next world; exhibiting himself to the world with the frenzy of a lunatic rather than as the founder of a sect, or as a promised saviour. It appears by the testimonies of Irenæus, Justin, and Tertullian, that he pretended to be one of the æons sent from the *pleroma*, or ecclesiastical regions, to succour the souls which lay groaning under bodily oppression and servitude, and to maintain them against the violence and stratagems of the dæmons who hold the reins of empire in this sublunary world. As this doctrine was placed upon the same foundation with that of Simon Magus, the ancient writers looked upon that personage as the instructor of Menander.

MENASSEH, Ben Israel, a celebrated rabbi, was born in Portugal about the year 1604. He was the son of Joseph Ben Israel, and followed his father into Holland, where he was educated by Rabbi Isaac Uziel, under whom he in a short time made so great progress in the Hebrew tongue, that at eighteen years of age he succeeded his instructor in the synagogue of Amsterdam. In this post he continued several years, and married Rachel, of the family of the Abarbanels, whom the Jews believe to be descended from King David. He afterwards went to his brother Ephraim, a rich merchant, who had settled at Basil, and by whose advice he entered into trade. Some time afterwards, the hopes of a more agreeable settlement induced him to visit England, then under the protectorship of Cromwell, who gave him a very favourable reception, and one day entertained him at his table with several other learned divines. However, he soon afterwards passed into Zealand, and died at Middleburg about the year 1657. The Jews of Amsterdam obtained his body, and interred it at their own expense. He was of the sect of the Pharisees, and possessed lively wit, solid judgment, and great learning, with all the virtues which adorn private life. He wrote many works in Hebrew, Latin, Spanish, and English. The principal of those published in Latin are, 1. His *Conciliator*, a learned and curious work, in which he endeavours to reconcile those passages of Scripture which seem to contradict each other; 2. *De Resurrectione Mortuorum;* 3. *De Termino Vitæ;* 4. *Dissertatio de Fragilitate Humana ex lapsu Adami, deque Divino in bono opere Auxilio;* and, 5. *Spes Israel.* Dr. Thomas Pococke has written his life in English.

MENDE, an arrondisement of the department of the Lozère in France, 731 square miles in extent. It contains seven cantons, divided into sixty-two communes, containing 48,250 inhabitants. The chief city of the same name is situated on a hill on the left bank of the Lot. It is ill-built, with narrow and crooked streets, and poor old houses. There is a cathedral with two towers, one of great singularity of architecture. It contains 910 houses, 5100 inhabitants, who make some few coarse cloths. Lat. 44. 20 47. N. Long. 3. 24. 27. E.

MENDELI, a considerable town of Irak Arabia, on the

Mendelsohn || Mendez.

Persian side, near the Turkish frontier. There is a mountain of Naphtha about thirty miles NE. of Bagdad.

MENDELSOHN, Moses, a Jew of Berlin, and one of the most celebrated writers of Germany, who died in that city in the year 1785, at the age of fifty-seven. His first attempt as an author was soon after 1767, when he published a work entitled *Jerusalem*, in which, besides other bold and unjustifiable opinions, he maintains, that the Jews have a revealed law but not a revealed religion; that opinions are not subjects of revelation; and that the only religion of the Jewish nation is that of nature. He acquired great reputation by his *Phædon*, or Discourses on the Immateriality and Immortality of the Soul, (translated into French 1773, 8vo.), in which he unfolds this important truth, which is the great foundation of all morality, with the wisdom of an enlightened philosopher united to the attractions of an elegant writer. In consequence of this excellent work, he was styled, by some of the periodical writers, the Jewish Socrates; but he wanted the firmness and the courage of the Grecian philosopher. His timidity, and even pusillanimity, defects too common in speculative men, prevented him from being of any essential service to his nation, of which he might have become the benefactor by being the reformer; whilst the pliancy of his character, and his modest, obliging disposition, gained him the esteem alike of the superstitious and the incredulous. After all, he could never procure admission into Berlin society, or access to the conversation of the king of Prussia. At his death he received from his nation those honours which are commonly paid to their most eminent rabbin. Though Mendelsohn was descended from a respectable family, he was very poor. In early life he entered into a counting-house of his own nation, in which he greatly recommended himself by his capacity and integrity in business; but philosophy and literature soon became his principal occupation; and to the famous Lessing he was indebted for counsels which, without diverting his attention from those pursuits that were necessary to his subsistence, accelerated his progress in his literary career. Even after the death of his benefactor, Mendelsohn retained for him the most sincere regard and the most lively gratitude. But notwithstanding the very strict regimen which he observed, he survived him only a few years, his feeble frame and weak constitution having been gradually undermined by intense application to study.

MENDEZ Pinto, Ferdinand, was born at Monte-mor-o-velho in Portugal, and was at first servant to a Portuguese gentleman. In expectation of making a fortune, he embarked for India in the year 1537. But his vessel being taken by the Turks on his passage out, he was carried to Mokkha, and sold to a Greek renegado, and afterwards to a Jew, in whose possession he continued till he was redeemed by the governor of Ormus, who procured him an opportunity of proceeding out to India, agreeably to his original design. During a residence of twenty-one years in that country, he was an eye-witness of many important transactions, and experienced many singular adventures. He returned in 1558, to Portugal, where he enjoyed the reward of his labours, after having been thirteen times a slave and sixteen times sold. A very curious account of his travels was written by himself, and published at Lisbon, in 1614, folio. This work was translated into French by Bernard Figuier, a Portuguese gentleman, and printed at Paris, in 1654, 4to. It is written in a very interesting manner and in a style more elegant than might have been expected from a man whose whole life had been spent in the camp and in slavery. It elucidates a great variety of particulars relating to the geography, history, and manners of the inhabitants of China, Japan, Pegu, Siam, Achem, Java, and other countries. But his name, like that of Munchausen, has unfortunately become the synonym of an imaginative romancer who sacrifices to a love of the marvellous or the incredible not only truth but probability.

Mendicants

MENDICANTS, or Begging Friars, several orders of religious, who, having no settled revenues, are supported by the charitable contributions they receive from others. This sort of society began in the thirteenth century; and the members of it, by the tenor of their institution, were destined to remain entirely destitute of all fixed revenues and possessions; though in process of time their number became a heavy tax upon the people. Innocent III. was the first of the popes who perceived the necessity of instituting such an order: and accordingly he conferred on those monastic societies, who made a profession of poverty, the most distinguishing marks of his protection and favour. They were also encouraged and patronized by the succeeding pontiffs, after experience had demonstrated their public and extensive usefulness. But when it became generally known, that they had such a peculiar place in the esteem and protection of the rulers of the church, their number increased to such a degree that they became a burden, not only to the people, but even to the church itself. The great inconvenience which arose from the excessive multiplication of the mendicant orders was remedied by Gregory X. in a general council, which he assembled at Lyons in the year 1272. Here all the religious orders which had sprung up after the council held at Rome in 1215, under the pontificate of Innocent III. were suppressed; and the disproportionate number of mendicants was reduced to four societies or denominations; namely, those of the Dominicans, Franciscans, Carmelites, and Augustinians or hermits of St. Augustin.

As the pontiffs allowed these four mendicant orders the liberty of travelling wherever they thought proper, of conversing with persons of every rank, of instructing the youth and the multitude wherever they went; and as those monks exhibited, in their outward appearance and manner of life, more striking marks of gravity and holiness than were observable in the other monastic societies; they rose all at once to the very summit of fame, and were regarded with the utmost esteem and veneration throughout every country of Europe. The enthusiastic attachment to these sanctimonious beggars went so far, indeed, that, as we learn from authentic records, several cities were divided or cantoned out into four parts, with a view to provide for the orders in question; the first part being assigned to the Dominicans, the second to the Franciscans, the third to the Carmelites, and the fourth to the Augustinians. The people were unwilling to receive the sacraments from any other hands than from those of the mendicants, to whose churches they crowded to perform their devotions, whilst living, and where they were also extremely desirous that their remains should be deposited after death. Nor did the influence and credit of the mendicants end here. For we find in the history of this and of the succeeding ages, that they were employed not only in spiritual matters, but also in temporal and political affairs of the greatest consequence; in composing the differences of princes, concluding treaties of peace, concerting alliances, presiding in cabinet councils, governing courts, levying taxes, and in other occupations, not only remote from, but altogether inconsistent with, the monastic character and profession. However, the power of the Dominicans and Franciscans greatly surpassed that of the other two orders: insomuch that before the Reformation, they were what the Jesuits have since been, namely, the very soul of the hierarchy, the prime engine of the state, the secret spring of all the motions of each, and the authors and directors of every important event, both in the religious and political world. By a natural progression their pride and confidence arrived at such a pitch, that they had the presumption to declare publicly, that they had a divine impulse and commission to illustrate and maintain the religion of Jesus; they treated with the utmost insolence and contempt all the different orders of the priesthood; they even affirmed, without a blush, that the true method of obtaining salvation was revealed to

Mendicity ‖ Menecrates.

them alone; they proclaimed, with ostentation, the superior efficacy and virtue of their indulgences; and they vaunted beyond measure their interest at the court of heaven, and their familiar connexions with the Supreme Being, the Virgin Mary, and the saints in glory. By these impious pretensions, they so deluded and captivated the miserable, and blinded the multitude, that the latter would not entrust any other but the mendicants with the care of their souls. Towards the close of the fourteenth century, they retained their credit and influence to such a degree, that great numbers of both sexes, some in health, others in a state of infirmity, and a third class at the point of death, earnestly desired to be admitted into the mendicant order, which they looked upon as a sure and infallible method of rendering heaven propitious. Many made it an essential part of their testaments, that their bodies after death should be wrapped in old ragged Dominican or Franciscan habits, and interred amongst the mendicants; for such were the superstition and ignorance of this age, that people universally believed they would the more readily obtain mercy from Christ, at the day of judgment, if they appeared before his great tribunal associated with the mendicant friars.

About this time, however, the mendicants fell into universal disrepute; but being resolutely protected against all opposition, whether open or secret, by the popes, who regarded them as their best friends and most effectual supporters, they suffered little or nothing from the efforts of their numerous adversaries. In the fifteenth century, besides their arrogance, which had grown excessive, a quarrelsome and litigious spirit prevailed amongst them, and drew upon them the just displeasure and indignation of many. At this time, by affording refuge in their order to the Beguines, they became offensive to the bishops, and were thereby involved in difficulties and perplexities of various kinds. They lost their credit in the sixteenth century by their rustic impudence, their ridiculous superstitions, their ignorance, their signal cruelty, and their brutish manners. They discovered the most barbarous aversion to the arts and sciences, and expressed a similar abhorrence of certain eminent and learned men, who endeavoured to open the paths of science to the pursuits of studious youth, recommended the cultivation of the mind, and attacked the barbarism of the age in their writings and discourses. In a word their general character, together with other circumstances, concurred to render a reformation desirable, and to bring about that happy event.

Amongst the number of mendicants are also ranked the Capuchins, Recollects, Minims, and others.

MENDICITY. This subject will be treated of in connection with the general subject of Pauperism. See Poor Laws.

MENDRISIO, a town of Switzerland, the capital of a district of the same name, in the canton of Tesino. It contains 1550 inhabitants, who are active and intelligent, and carry on much silk spinning. Being situated on the southern declivity of the Alps, the climate and productions resemble more those of Italy than the rest of Switzerland. It is only three miles from Lugarno, and nine from the lake of Como, and yields excellent wheat, wine, tobacco, and silk. It consists chiefly of one long street, with a collegiate church, a Capuchin convent, and a nunnery of Ursulines.

MENDYGHAUT, a town of Hindustan, in the province of Agra, situated on the west side of the Ganges, sixty miles W. by N. from Lucknow; it is enclosed by a mud wall, and two small rivulets. Long. 79. 57. E. Lat. 27. 3. N.

MENE, a Chaldaic word, which signifies "he has numbered or counted," being one of the three words which were written upon the wall by the hand that appeared to Belshazzar, the last king of Babylon, the night on which he was put to death. See Belshazzar.

MENECRATES, a physician of Syracuse, who flourished about 360 before Christ, was famous for his skill in his profession, but much more for his vanity. He was always attended by some of the patients he had cured, and with whom he previously stipulated that they should follow him whithersoever he went. One appeared with the attributes of Hercules, another with those of Apollo, and others again with those of Mercury or Æsculapius; whilst he, clad in a purple robe, with a golden crown on his head, and a sceptre in his hand, presented himself, to the admiration of the public, under the name of Jupiter, and travelled through different countries escorted by these counterfeit deities.

Menedemus ‖ Menin.

MENEDEMUS, a Greek philosopher, was a native of Eretria, the chief city of Eubœa. He was the son of Clisthenes, a man of noble birth but in poor circumstances. In his youth Menedemus is said to have been employed in sewing the canvass of tents. The precise period of his birth and death is unknown to us, but he was the contemporary of Aretus, Lycophron, and Antagoras of Rhodes. He therefore flourished probably from about B.C. 300 to 279. Menedemus having been sent with a body of troops to the assistance of Megara, seems to have there studied philosophy under Stilpo, and then proceeded to Elis, which was distinguished for the Eliac sect, founded by Phædo. It was afterwards called the Eretrian school, from Menedemus, who taught the same doctrines. On his return to his native place, he began to give lessons in philosophy, and was distinguished for the dignified character of his eloquence, and the gravity of his deportment. He was remarkable for his temperate mode of living, which his friend Lycophron (see Lycophron) satirized in a poem entitled *Menedemus*. He was employed by his countrymen in the highest offices of the state; but having been accused of favouring the cause of the Macedonians, he was obliged to leave his country, and proceed to Antigonus Gonatas. In this situation, he tried to rescue his ungrateful country from slavery, but Antigonus refused to listen to his petition, upon which Menedemus ended his life by abstinence from food for seven days. The life of Menedemus is written by Diogenes Laërtius.

MENEHOUD, St., an arrondisement of the department of the Marne in France. It extends over 476 square miles, and contains 32,500 inhabitants. It is divided into three cantons, and subdivided into fifty-two communes. The capital, of the same name, stands on an island of the river Aisme, where the smaller river Auve falls into it. It contains 750 houses and 3600 inhabitants, who make some thread lace, and trade extensively in fire-wood. This place has become celebrated from its being the spot where the united armies of Austria and Prussia received the first check, when invading France in the autumn of the year 1792.

MENELAUS, the son of Atreus, and the brother of Agamemnon, was the reigning king of Sparta, when Paris deprived him of his wife Helen. This rape occasioned the famous war of Troy.

MENES, born at a town of Thebais or Saïd, in Upper Egypt, was the founder of the Egyptian empire. He had three sons; Athotis, who ruled after him at This and Thebes; Curudes, who in Lower Egypt founded the kingdom of Heliopolis, which was afterwards the kingdom of the Diospolitans; and Necherophes, who reigned at Memphis. It is believed that this Menes reigned 117 years after the birth of Phaleg, son of Heber, which took place in the very year of the dispersion of mankind throughout the whole earth. In building Memphis, he stopped the Nile near it, by the construction of a causeway one hundred furlongs broad, which he caused to run through the mountains.

MENIALS, domestic or household servants, who live under their lord or master's roof.

MENIN, a city of the Netherlands, in the province of West Flanders, and arrondisement of Courtray. It is situated on the river Lys, which is the boundary towards France. It is strongly fortified, and contains 4560 inhabitants, who manufacture linen, woollen, and cotton goods, lace, paper,

Menippean || Mennonites

leather, and snuff, and carry on a considerable trade in corn, cattle, and flax. Lat. 50. 49. N. Long. 2. 59. E.

MENIPPEAN *(Satira Menippea)*, a kind of satire consisting of prose and verse intermixed. It is so called from Menippus, a Cynic philosopher, who delighted in composing satirical letters in this style. In imitation of him Varro also wrote satires under the title of *Satiræ Menippeæ;* and hence this sort of composition is also denominated *Varronian satire.* Amongst the moderns there is a celebrated piece under this title, which was first published in 1594, against the chiefs of the league, called also the *Catholicon* of Spain. It is esteemed a masterpiece for the time.

MENIPPUS, a Cynic philosopher, with whose private history we are but very slightly acquainted. Neither his birth-place nor the time during which he flourished, are known with any degree of precision. It is supposed that he was a native of Gadara, a small village of Phœnicia, (Strab. xvi. 759), and that he lived before the year 200 B.C., as he is spoken of by Hermippus, according to Diogenes Laërtius. He was originally a slave, but having purchased his liberty, he settled at Thebes, where he obtained the rights and privileges of a citizen. He devoted himself to usury, and amassed a considerable sum of money, but having been robbed, he fell into such despair that he hanged himself. This is the statement of Diogenes Laërtius, but the character left of him by the ancients does not agree with it. He was a follower of the Cynic philosophy, and regarded with contempt the luxuries of life. Lucian, in his *Dialogues of the Dead*, makes Diogenes describe him as "old, bald-headed, wearing a threadbare cloak, with abundance of apertures in it, pervious to every wind, and patched with rags of all possible colours; and as laughing incessantly at those conceited pedants, the philosophers, who are generally the objects of his derision." Lucian has introduced Menippus in many of his dialogues, and always as a man despising the perishable things of this life. Varro, in his *Satires*, imitated the style of Menippus, so that they were called *Satiræ Menippeæ.* (Cic. 1, 2. Gell. xi. 18., xiii. 30.)

MENNONITES, a sect in the United Provinces, and in most respects the same with those who were, in other places, called *Anabaptists.* They had their rise in 1536, when Menno Simon, a native of Friesland, who had been a Catholic priest, and a notorious profligate, resigned his rank and office in the Catholic church, and publicly embraced the communion of the Anabaptists.

Menno was born at Witmarsum, a village in the neighbourhood of Bolswert in Friesland, in the year 1505, and died in 1561 in the duchy of Holstein, at the country-seat of a certain nobleman not far from the city of Oldesloe, who, moved with compassion by a view of the perils to which Menno was exposed, and the snares which were daily laid for his ruin, took him with certain of his associates under his protection, and gave them an asylum. The writings of Menno, which are almost all composed in the Dutch language, were published in folio at Amsterdam in the year 1651. About the year 1537, Menno was earnestly solicited by many of the sect with which he connected himself, to assume amongst them the rank and functions of a public teacher; and hence he looked upon the persons who made this proposal as exempt from the fanatical frenzy of their brethren at Munster, though according to other accounts, they were originally of the same stamp, only rendered somewhat wiser by their sufferings, he yielded to their entreaties. From this period to the end of his life, he travelled from one country to another with his wife and children, exercising his ministry, under difficulties and calamities of various kinds, and constantly exposed to the danger of falling a victim to the severity of the laws. East and West Friesland, together with the province of Groningen, were first visited by the zealous apostle of the Anabaptists; from thence he directed his course towards Holland, Guelderland, Brabant, and Westphalia, continued it throughout the German provinces situated on the coasts of the Baltic Sea, and penetrated as far as Livonia. In all these places his ministerial labours were attended with remarkable success, and added to his sect a prodigious number of followers. Hence he is deservedly considered as the common chief of almost all the Anabaptists, and the parent of the sect which still subsists under that denomination. Menno was a man of genius, undirected by sound judgment. He possessed a natural and persuasive eloquence, and such a degree of learning as made him pass for an oracle in the estimation of the multitude. He appears, moreover, to have been a man of probity, of a meek and tractable spirit, gentle in his manners, pliable and obsequious in his commerce with persons of all ranks and characters, and extremely zealous in promoting practical religion and virtue, which he recommended by his example as well as by his precepts. The plan of doctrine and discipline drawn up by Menno was of a much more mild and moderate nature than that of the furious and fanatical Anabaptists, whose tumultuous proceedings have been recited under that article, but somewhat more severe, though more clear and consistent than the doctrine of the wiser branches of that sect, who aimed at nothing more than the restoration of the Christian church to its primitive purity. Accordingly he condemned the plan of ecclesiastical discipline which was founded on the prospect of a new kingdom, to be miraculously established by Jesus Christ upon the ruins of civil government and the destruction of human rulers, and which had proved the fatal source of dreadful commotions, frequent rebellions, and enormous crimes. He declared publicly his dislike of that doctrine, which pointed out the approach of a marvellous reformation in the church by the means of a new and extraordinary effusion of the Holy Spirit. He expressed his abhorrence of the licentious tenets, which several of the Anabaptists had maintained, with respect to the lawfulness of polygamy and divorce; and finally, he considered as unworthy of toleration those fanatics who were of opinion that the Holy Ghost continued to descend into the minds of many chosen believers, in as extraordinary a manner as he did at the first establishment of the Christian church, and that he testified this peculiar presence to several of the faithful by miracles, predictions, dreams and visions of various kinds. He retained, indeed, the doctrines commonly received amongst the Anabaptists, in relation to the baptism of infants, the *millennium* or reign of Christ upon earth for a thousand years, the exclusion of magistrates from the Christian church, the abolition of war, the prohibition of oaths enjoined by our Saviour, and the vanity as well as the pernicious effects of human science. But whilst Menno retained these doctrines in a general sense, he explained and modified them in such a manner as made them resemble the religious tenets which were universally received in the Protestant churches; and this rendered them agreeable to many, and made them appear inoffensive even to numbers who had no inclination to embrace them. It happened, however, that the nature of the doctrines considered in themselves, the eloquence of Menno which set them off to such advantage, and the circumstances of the times, gave a high degree of credit to the religious system of this famous teacher amongst the Anabaptists, so that it made rapid progress in various parts. And thus it was in consequence of the ministry of Menno, that the different sorts of Anabaptists agreed together in excluding from their communion the fanatics who dishonoured it, and in renouncing all tenets that were detrimental to the authority of civil government; and by an unexpected coalition they formed themselves into one community.

Mennonites

Though the Mennonites usually pass for a sect of Anabaptists, yet Mr. Herman Schyn, a Mennonite minister, who has published their history and apology, maintains, that they are not Anabaptists either in principle or in origin. No-

Mennonites

thing, however, can be more certain than this fact, that the first Mennonite congregations were composed of the different sorts of Anabaptists, of those who had been always inoffensive and upright, and of those who, before their conversion by the ministry of Menno, had been seditious fanatics. Besides, it is alleged that the Mennonites do actually retain, even at this day, some of those opinions and doctrines, which led the seditious and turbulent Anabaptists of old to the commission of so many enormous crimes; such particularly is the doctrine concerning the nature of Christ's kingdom, or the church of the New Testament, though modified so as to have lost its noxious qualities, and to be no longer pernicious in its influence.

The Mennonites are subdivided into several sects, the two principal of which are the FLANDRIANS or FLEMINGIANS, and the WATERLANDIANS. The opinions, says Mosheim, that are held in common by the Menonnites, seem to be all derived from this fundamental principle, that the kingdom which Christ established upon earth is a visible church or community, into which the holy and just alone are to be admitted, and which is consequently exempt from all those constitutions and rules of discipline that have been invented by human wisdom, for the correction and reformation of the wicked. This principle, indeed, was avowed by the ancient Mennonites, but it is now almost wholly renounced; nevertheless, from this ancient doctrine, many of the religious opinions that distinguish the Mennonites from all other Christian communities, seem to be derived. In consequence of this doctrine, they admit none to the sacrament of baptism but persons who are come to the full use of their reason; they neither admit civil rulers into their communion, nor allow any of their members to perform the functions of magistracy; they deny the lawfulness of repelling force by force, and consider war, in all its shapes, as unchristian and unjust; they entertain the utmost aversion to the execution of justice, and more especially to capital punishments; and they also refuse to confirm their testimony by an oath. The particular sentiments which divided the more considerable societies of the Mennonites are the following: The rigid Mennonites, called the *Flemingians*, maintain with various degrees of rigour, the opinions of their founder Menno, as to the human nature of Christ, alleging that it was produced in the womb of the Virgin by the creating power of the Holy Ghost; the obligation that binds us to wash the feet of strangers, in consequence of our Saviour's command; the necessity of excommunicating and avoiding, as one would do the plague, not only avowed sinners, but also all those who depart, even in some slight instances pertaining to dress, &c. from the simplicity of their ancestors; the contempt due to human learning, and other matters of less moment. However, this austere system declines, and the rigid Mennonites are gradually approaching towards the opinions and discipline of the more moderate or *Waterlandians*.

Menology ‖ Mensuration.

The first scttlement of the Mennonites in the United Provinces, was granted them by William Prince of Orange, towards the close of the sixteenth century; but it was not before the following century that their liberty and tranquillity were fixed upon solid foundations, when, by a confession of faith published in the year 1626, they cleared themselves from the imputations of those pernicious and detestable errors that had been laid to their charge. In order to appease their intestine discords, a considerable part of the anabaptists of Flanders, Germany, and Friesland, concluded their debates in a conference held at Amsterdam, in the year 1630, and entered into the bonds of fraternal communion, each reserving to themselves a liberty of retaining certain opinions. This association was renewed and confirmed by new resolutions, in the year 1649; in consequence of which, the rigorous laws of Menno and his successors were, in various respects, mitigated and corrected.

MENOLOGY, MENOLOGIUM, (from *μην*, *month*, and *λογος*, *discourse*), is much the some as martyrology, or calendar, in the Latin. The Greek menologium is divided into the several months in the year, and contains an abridgment of the lives of the saints, with a bare enumeration of the names of those whose lives were never written. The Greeks have various menologies; and the Romans tax them with inserting divers heretics in their menologies as saints.

MENSA, in law books, a term which includes in it all patrimony, and necessaries for livelihood.

MENSALS, MENSALIA, in church history, such livings as were formerly united to the tables of religious houses, and hence called *mensal benefices*.

MENSORES, amongst the Romans, were harbingers, whose business it was to go before the emperor, and fix upon lodgings for him when he travelled into any of the provinces. They also marked out encampments, and assigned every regiment its post.

Mensores were likewise land-surveyors, architects, or appraisers of houses and public buildings. The distributors of provisions in the army were called *mensores frumentarii*; and the appellation of *mensores* was also applied to servants who waited at table.

MENSURATION.

EVERY branch of the mathematics which has for its object the comparison of geometrical quantities, and the determination of their proportions to each other, may be comprehended under the general name *Mensuration*. So that, taking the term in its most extensive sense, whatever is delivered in this work under the titles GEOMETRY, TRIGONOMETRY, CONIC SECTIONS, part of ALGEBRA, and a very considerable portion of FLUXIONS, may be considered as constituting particular branches of this general theory.

The term mensuration, however, is also frequently used in a less extensive sense, and is applied to a system of rules and methods by which numerical measures of geometrical quantities are obtained. And it is to this limited view of the subject that we propose to confine our attention in the present treatise. In general, it will only be necessary to give the practical rules, as we have already explained their foundation when treating of GEOMETRY, CONIC SECTIONS, and FLUXIONS; but, in addition to the rules, in a few instances, we shall give their demonstrations.

In all practical applications of mathematics it is necessary to express magnitudes of every kind by numbers. For this purpose a line of some determinate length, as one inch, one foot, &c., is assumed as the measuring unit of lines, and the number expressing how often this unit is contained in any line, is the numerical value or measure of that line.

A surface of some determinate figure and magnitude is assumed as the measuring unit of surfaces, and the number of units contained in any surface is the numerical measure of that surface, and is called its *area*. It is usual to as-

Table of measures.

sume, as the measuring unit of surfaces, a square, whose side is the measuring unit of lines.

A solid of a determinate figure and magnitude is in like manner assumed as the measuring unit of solids, and the number of units contained in any solid is its solidity or content. The unit of solids is a cube, each of whose edges is the measuring unit of lines, and consequently each of its faces the measuring unit of surfaces.

A right angle is conceived to be divided into ninety equal angles; and one of these, called an angle of one degree, is assumed as the measuring unit of angles.

The measures generally employed in the application of mensuration to the common affairs of life, and their proportions to each other, are expressed in the following tables:

Table of Imperial Lineal Measure.

1 Foot	=	12 Inches.
1 Yard	=	3 Feet.
1 Pole or Perch	=	5½ Yards.
1 Furlong	=	40 Poles or Perches.
1 Mile	=	8 Furlongs.

1 Link	=	7·92 Inches.
1 Chain	=	100 Links=4 Poles=66 Feet.
1 Furlong	=	10 Chains.
1 Mile	=	80 Chains.

These measures were recognised and established by an act of Parliament in 1825; but they were the measures in common use before that time. The length of the standard yard is the distance between two points marked on a straight rod of brass commonly called *Bird's Standard Yard of* 1760. The length of the yard is to that of a pendulum vibrating seconds of mean time in the latitude of London, in a vacuum at the level of the sea, as 36 to 39·1393, the temperature of the brass rod being 62° of Fahrenheit's thermometer.

Table of Imperial Superficial Measure.

1 Square Foot	=	144 Square Inches.
1 Square Yard	=	9 Square Feet.
1 Sq. Pole or Perch	=	30¼ Square Yards.
1 Square Chain	=	16 Sq. Poles=10,000 Sq. Links.
1 Rood	=	40 Sq. Poles=2½ Sq. Chains.
1 Acre	=	4 Roods=10 Sq. Chains.

Table of Scottish Lineal Measure,

Derived from the Scottish Standard Ell, in the custody of the town of Edinburgh.

1 Scotch Link	=	8·89435	} Imperial Inches.
1 — Foot	=	12·0194	
1 — Ell	=	37·0598	
1 — Fall	=	6 Scotch Ells.	
1 — Chain	=	100 — Links=74·1196 Imp. Ft.	
1 — Furlong	=	1000 — Links.	
1 — Mile	=	1976·522 Imperial Yards.	

Note. We have given these Scottish measures for the purpose of comparison with Imperial measure, by which the Scottish measures, being now set aside, will be gradually superseded.

Table of Scottish Superficial Measure.

1 Square Fall	=	36 Square Ells.	
1 Rood	=	40 Square Falls.	
1 Acre	=	4 Roods.	
1 Scotch Acre	=	1·26118345	} Imp. Acres.
1 — Rood	=	0·3153	
1 — Fall	=	0·007882	
1 — Ell	=	0·000219	

Right lines and angles.

Note 1. To convert *Scotch* acres into *Imperial*, to the number of Scotch acres add its ¼th, also its $\frac{1}{9\,0}$th; and in addition to these, if accuracy be required, the $\frac{1}{1\,6\,0}$th part of the $\frac{1}{9\,0}$th. Suppose, for example, 100,000 Scotch acres are to be converted into Imperial acres:

To		100,000
add ¼ of 100,000	=	25,000
$\frac{1}{9\,0}$ of 100,000	=	1,111
$\frac{1}{1\,6\,0}$ of 1111	=	7
100,000 Scotch acres	=	126,118 Imperial.

2. The same rule will apply to the conversion of rent or value, and produce of Scotch acres.

Table of Imperial Liquid and Dry Measures.

1 Pint	=	4 Gills.
1 Quart	=	2 Pints.
1 Pottle	=	2 Quarts.
1 Gallon	=	2 Pottles.
1 Peck	=	2 Gallons.
1 Bushel	=	4 Pecks.
1 Coomb	=	4 Bushels.
1 Quarter	=	2 Coombs.

1 Old English Wine Gallon	=	231 Cubic Inches.
1 Imperial Wine Gallon	=	277·274 do.

The Imperial gallon is the space occupied by 10 lbs. of water, weighing 70,000 grains.

1 Old English Ale Gallon = 282 Cubic Inches.

The Imperial ale gallon is now the same as the Imperial wine gallon.

The Winchester bushel measure is a cylinder 18½ inches wide, and eight inches deep, and contains 2150.4252 cubic inches.

The Imperial bushel contains 2218·191 cubic inches.

Table of Scottish Liquid Measure.

1 Mutchkin	=	4 Gills.
1 Choppin	=	2 Mutchkins.
1 Pint	=	2 Choppins.
1 Gallon	=	8 Pints.

The Standard Pint is the *Stirling Jug*, which contains 104·2034 cubic inches, and holds 26,306·982 grains of distilled water, at 62° of Fahrenheit's thermometer, the height of the barometer being 30 inches.

The Scotch Gallon = 3·0065122 Imperial Gallons.

Table of Scottish Dry Measure.

1 Peck	=	4 Lippies or Forpets.
1 Firlot	=	4 Pecks.
1 Boll	=	4 Firlots.
1 Chalder	=	16 Bolls.

The Linlithgow Wheat Firlot is to the Imperial Standard Bushel as 0·998256 to 1. This is not far from a ratio of equality, so that the Scotch Standard Wheat Boll, Firlot, Peck, and Lippie nearly correspond with the Imperial Coomb and its submultiples, the Bushel, Peck, and Pottle.

The Linlithgow Barley Firlot is to the Imperial Standard Bushel as 1·4562794 to 1.

SECTION I.—OF THE MENSURATION OF RIGHT LINES AND ANGLES.

The rules by which certain of the sides or angles of a triangle are to be found, when other sides and angles are

Right lines and angles.

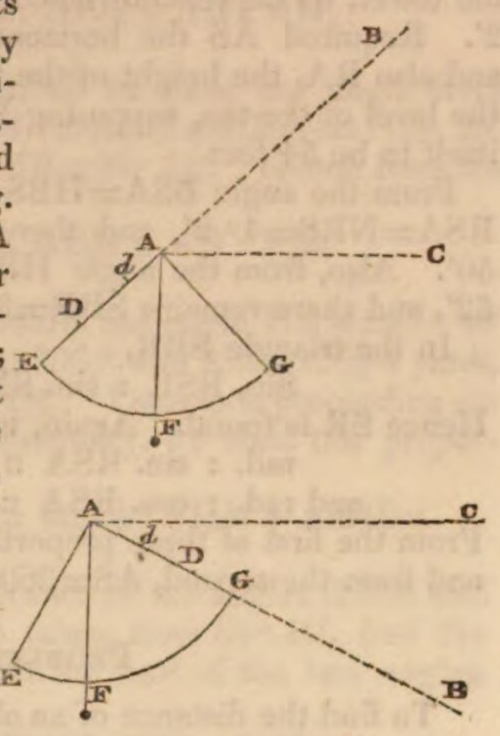
given, might be considered as belonging to this part of mensuration. But as these are fully investigated and explained in the article PLANE TRIGONOMETRY, it is not necessary to deliver them also here. Referring therefore to that article, we shall employ the remainder of this section in the application of trigonometry to the mensuration of heights and distances.

Mensuration of Heights and Distances.

By the application of geometry the measurement of lines, which, on account of their position or other circumstances, are inaccessible, is reduced to the determination of angles, and of other lines which are accessible, and admit of being measured by methods sufficiently obvious.

A line considered as traced on the ground may be measured with rods or a Gunter's chain of sixty-six feet; but more expeditiously with measuring tapes of fifty or one hundred feet. By these, if the ground be tolerably even, and the direction of the line be traced pretty correctly, a distance may, by using proper care, be measured within about three inches of the truth in every fifty feet, so that the error may not exceed the 200th part of the whole line.

Vertical angles may be measured with a quadrant furnished with a plummet and sights in the manner indicated by the annexed figures. If an angle of elevation is to be measured, as the angle contained by a horizontal line AC, (fig. 1,) and a line drawn from A to B the top of a tower, hill, or other eminence; or to a celestial body, as a star, &c.; the centre of the quadrant must be fixed at A, and the instrument moved about A, in the vertical plane, till to an eye placed at G, the object B be seen through the two sights D, *d*. Then will the arch EF, cut off by the plumb-line AF, be the measure of the angle CAB.



An angle of depression CAB (fig. 2), is to be measured exactly in the same manner, except that here the eye is to be placed at A the centre of the instrument, and the measure of the angle is the arch EF.

Pl. CCCLIII, fig. 1.

But the most convenient instrument for measuring angles, whether vertical or horizontal, is the *Theodolite*. This instrument has undergone various alterations and improvements since it was described (we believe, for the first time) by Sisson. Its principal parts are,

1. *The horizontal limb.* This consists of two circular plates AA, the upper or vernier plate, and BB, the graduated limb. The former moves freely above the latter, without actual contact, and both have a horizontal motion about a vertical axis C, which consists of two parts, one external, fixed to the graduated limb B, and another internal, fixed to the vernier plate A. Their form is conical, and they are ground and accurately fitted into each other, so as to have a perfectly steady motion. The external centre also fits into a ball at D, and the parts are held together by a screw at the lower end of the internal axis.

The lower plate is broader than the upper, and its edge is chamfered off and covered with silver to receive the graduations.

2. *The verniers.* These are short scales on the upper plate, and on opposite sides of it, or 180° asunder. They are chamfered, so as to form with the chamfered edge of the lower plate a continued conical surface, and are covered with silver, and graduated in such a manner as to subdivide the divisions of the lower plate into minutes. By means of microscopes which are generally fixed over the verniers, the half or even the fourth of a minute may be estimated.

Right lines and angles.

3. *The parallel plates* F and G. These serve for levelling the instrument, and are held together by a ball and socket at D. Four milled-headed screws H, H, &c., enter and work in the lower plate, while their upper ends press against the lower side of the upper plate; and being set in pairs opposite to each other, they act in contrary directions, and by this means the instrument is set up level for observation.

Beneath the parallel plates is a female screw adapted to the *staff-head*, which is united by brass joints to three mahogany legs, so constructed, that when shut up they form one round staff, and are secured in that form by rings put on them. When opened out they make a very firm stand, and the parallel plates may be made horizontal, although the ground may be uneven.

The lower plate of the horizontal limb can be fixed in any position by tightening the clamping screw I, which causes the collar K to embrace the axis C, and prevents its moving; but the final adjustment is to be given by means of the slow-motion tangent screw L which is attached to the upper parallel plate. In like manner the upper or vernier plate can be fixed to the lower by a clamp M, which is also furnished with a slow motion, produced by a tangent screw.

4. *Spirit levels* N, N. There are two of these at right angles to each other, with proper adjusting screws, on the plane of the vernier plate. Their use is to determine when the horizontal limb is set truly level.

5. The *compass.* This is on the middle of the vernier plate, but of course it cannot be shewn in a side view of the instrument.

6. The *vertical arc* and *telescope.* The arc is placed on a horizontal axis, the ends of which are supported by two frames, (only one of which can be shewn in the figure.) At one end of the axis is an arm R, with a clamping screw S, by which the axis is held when the telescope is nearly in the proper position: and there is a tangent screw T, by which a slow angular motion is given to the vertical arc and telescope to direct the latter accurately to an object. One side of the vertical arc is inlaid with silver, and by means of its vernier V can be read off to single minutes. The other side shews the difference between the hypothenuse and the base of a right angled triangle, or the number of links to be deducted from each chain length to reduce hypothenusal to horizontal lines.

The level which is shewn under, and parallel to, the telescope is attached to it at one end by a joint, and at the other by a capstan headed screw for raising or lowering that end: there is another screw at the jointed end for lateral adjustment: by their united action the level is placed parallel to the optical axis or *line of collimation* of the telescope.

The telescope has two collars or rings of bell metal, ground truly cylindrical, on which it rests on its supports X, X, called Y's; and it is confined in its place by the clips Z, Z, which may be opened by removing the pins Y, Y, for the purpose of reversing the telescope or allowing it a circular motion round the axis during the adjustment.

In the focus of the eye glass are placed three lines formed of spider's web, one horizontal and two crossing it obliquely at equal angles so as to include a small angle between them. These are preferable to a single perpendicular wire, because a station staff at a distance can be made to bisect the angle formed by the oblique wires with more certainty than the staff can be bisected by a vertical wire.

Three of the four screws for adjusting the cross-wires are shewn at *a*, *a*, *a*, two of which are placed at right angles to the other two, so that by easing one of each pair and tightening the other opposite to it, the intersection of the wires may be placed exactly in the line of collimation.

Right lines and angles.

The object glass of the telescope is fixed in a tube which slides within the outer tube, and may be thrust out or drawn backward by turning the milled head *b* on the side of the telescope. By this motion the optical image of any object to which the telescope is directed may be brought to the intersection of the cross wires.

Before the theodolite can be applied to accurate practice its parts must be adapted to each other by means of the clamps and screws and levels. The operations by which this is performed are called *adjustments*.

The first adjustment is that of the line of collimation, which must coincide with the axis of the cylindrical rings on the telescope, and pass through the intersection of the cross wires. The second places the level attached to the telescope parallel to the rectified line of collimation. The third makes the axis of the horizontal limb truly vertical by means of the telescope level, which is most to be depended on; and then the levels on the vernier plate are adjusted by their screws so that their air bubbles may remain at rest in the middle of their tubes while it makes a complete revolution on its axis. When these adjustments are perfect the vernier of the vertical arc must be set so that its index may point to *zero* on the arc; or else its deviation from *zero* must be noted and applied as an index error.

Problem I.

To determine the height of an object, the bottom of which is accessible.

Plate CCCLIII. Fig. 2.

Example. Having measured AE, a distance of 200 feet in a direct horizontal line from the bottom of a tower, the angle BCD, contained by the horizontal line CD: and a line drawn from C to the top of the tower, was measured by a quadrant, or theodolite placed at C, and found to be 47° 30′. The centre C of the instrument was five feet above the line AE at its extremity E. It is required hence to determine AB the height of the tower.

In the right-angled triangle CBD we have given the side CD=200 feet, and the angle C=47° 30′. And since by the rules of Plane Trigonometry,

rad. : tan. BCD :: DC : DB;

By employing logarithmic tables and proceeding as is taught in Plane Trigonometry, we shall find DB=218.3 feet. To which add DA=EC=5 feet, the height of the instrument, and we have AB=223.3 feet, the height of the tower.

Problem II.

To determine the height and distance of an object when the bottom or point directly under it is inaccessible.

Fig. 3.

Ex. 1. Suppose a small cloud, or balloon C, is seen at the same time by two observers at A and B, and that these stations are in the same vertical plane with the object C, and on the same side of it. Also suppose that its angles of elevation, viz. the angles A and B are 35° and 64°, and that AB, the distance between the observers, is 880 feet. It is required hence to determine CD the height of the object, also AC, BC its distances from the two observers.

In the triangle CAB there are given the outward angle CBD=64°, and one of the inward angles A=35°; hence the other inward angle ACB, which is their difference, is given, and =64° —35°=29°.

Now in the triangle CAB

Sin. ACB : sin. A :: AB : BC,
and sin. ACB : sin. B :: AB : AC.

From these proportions, by actual calculation, BC will be found =1041 feet, and AC=1631 feet.

Again, in the right-angled triangle BCD

rad. : sin. B :: BC : CD.

Hence CD will be found =936 feet.

Fig. 4.

Ex. 2. To measure the height of an obelisk CD, standing on the top of a declivity, two stations at A and B were taken, one at the distance of forty, and the other at the distance of one hundred feet from the centre of its base, which was in a straight line with the stations. At the nearer station A, a line drawn from it to the top of the obelisk was found to make an angle of 41° with the plane of the declivity; and at B, the more remote station, the like angle was found to be 23° 45′. Hence it is required to find the height of the obelisk.

Right lines and angles.

From the angle CAD=41°, subtract the angle B=23° 45′, and there remains the angle BCA=17° 15′.

In the triangle BCA,

Sin. BCA : sin. B :: AB : AC. Hence AC=81.49 feet.

And in the triangle ACD,

AC+AD : AC—AD :: tan. $\frac{1}{2}$ (D+C) : tan. $\frac{1}{2}$ (D—C).

Hence $\frac{1}{2}$ (D—C)=40° 24′$\frac{1}{2}$, which, subtracted from $\frac{1}{2}$ (D+C,) gives the angle ACD=27° 5′$\frac{1}{2}$.

Lastly, in the triangle ACD,

Sin. ACD : sin. A :: AD : DC.

Hence DC, the height required, will be found to be 57·62 feet.

Fig. 5.

Ex. 3. At B the top of a tower which stood on a hill near the sea shore, the angle of depression of a ship at anchor (viz. the angle HBS), was 4° 52′; and at R, the bottom of the tower, its depression (namely, the angle NRS) was 4° 2′. Required AS the horizontal distance of the vessel: and also RA, the height of the bottom of the tower above the level of the sea, supposing RB the height of the tower itself to be 54 feet.

From the angle BSA=HBS=4° 52′, subtract the angle RSA=NRS=4° 2′, and there remains the angle BRS=50′. Also, from the angle HBA=90° subtract HBS=4° 52′, and there remains SBR=85° 8′.

In the triangle SBR,

Sin. BSR : sin. SBR :: BR : SR;

Hence SR is found. Again, in the triangle SRA,

rad. : sin. RSA :: SR : AR,
and rad. : cos. RSA :: SR : AS.

From the first of these proportions we find AR=260 feet; and from the second, AS=3690 feet.

Problem III.

To find the distance of an object from either of two given stations: also from a line joining them, when each station and the object can be seen from the other station.

Fig. 6.

Ex. 1. Wanting to know the breadth CD of a river, and also the distance of an object A close by its side from another object C on its opposite side, a base AB of 400 yards was measured along the bank. Then, by meaus of a theodolite, the angles CBA and CAB were measured, and found to be 37° 40′ and 59° 15′ respectively. It is required thence to determine the breadth CD, and the distance AC between the objects A and C.

This problem differs from the last only by the given angles, and distances required, lying in a horizontal instead of a vertical plane.

In the triangle ABC we have the base AB, also the angles A and B, and consequently the angle C given. And by Plane Trigonometry,

Sin. ACB : sin. B :: AB : AC.

Hence AC is found to be 246.2 yards.

Also, in the right-angled triangle ACD,

rad. : sin. A :: AC : CD.

Hence CD is found to be 211.6 yards.

Fig. 7.

Ex. 2. From a ship at sea a point of land was observed to bear E. by S.; and after sailing N. E. twelve miles, the same point was found to bear S. E. by E. How far was the last observation made from the point of land?

Let A be the first position of the ship, B the second, and C the point of land. In the triangle ABC we have given the angle A=5 points or 56° 15′, the angle B=9 points, or

Right lines and angles.

101° 15′, and the angle C=2 points or 22° 30′. Also the side AB=12 miles. Hence (by TRIGON.) the side BC is readily found to be 26.073 miles.

PROBLEM IV.

To determine the distance between two inaccessible objects, which can be seen from two given stations at a known distance from each other, supposing them all in the same plane.

Fig. 8.

Ex. Wanting to know the distance between two inaccessible objects H and M, a base AB of 670 yards was measured in the same plane with the objects, and the following angles were taken at its extremities.

$$\text{At A}\begin{cases}\text{BAM}=40^\circ\ 16'\\ \text{MAH}=57\ \ 40\end{cases}\qquad \text{At B}\begin{cases}\text{ABH}=42^\circ\ 22'\\ \text{HBM}=71\ \ \ 7\end{cases}$$

Hence it is required to determine HM, the distance between the objects.

In the triangle HAB we have the angle HBA=42° 22′, the angle HAB (=HAM+MAB)=97° 56′, and therefore the remaining angle AHB=39° 42′. We have also the side AB=670 yards. Hence, by this proportion,

Sin. AHB : sin. HBA :: AB : AH,

we find AH=706·8 yards.

Again, in the triangle MAB we have the angle MAB =40° 16′, the angle ABM (=ABH+HBM)=113° 29′, and therefore the angle AMB=26° 15′. Hence from the proportion,

Sin. AMB : sin. ABM :: AB : AM,

we get AM=1389·4.

In the triangle HAM, besides the angle HAM=57° 40′ we have now the sides AH=706·8, and AM=1389·4 yards, to find the remaining side HM. Therefore, proceeding according to the rules of trigonometry, we state this proportion,

AM+AH : AM—AH :: tan. $\frac{1}{2}$ (AHM+AMH) : tan. $\frac{1}{2}$ (AHM—AMH).

Hence we find half the difference of the angles AHM and AMH to be 30° 36′, which taken from 61° 10′, half the sum, leaves 30° 34′ for AMH the least of the two angles. Lastly, from the proportion

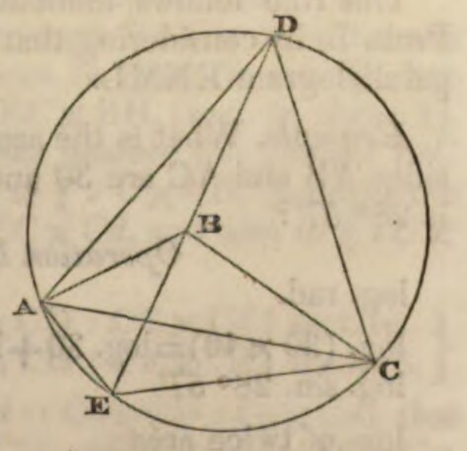
Sin. HMA : sin. HAM :: HA : HM,

we get HM=1174 yards, the answer to the question.

PROBLEM V.

The mutual distances of three remote objects being given, and the angles which these distances subtend at a station, in their plane, to find the position of the station.

Example. There are three objects, A, B, C, whose distances asunder are known to be as follows: namely, from A to B 106½, from A to C 202, and from B to C 131 fathoms. Now to determine the distance of D a fourth object, or station, from each of the other three, the angle ADB was measured with a theodolite, or other suitable instrument, and found to be 13° 30′, and the angle CDB was found 29° 50′. Hence it is required to determine the distances DA, DB, and DC, supposing DB the least of the three.



Let a circle be described through the points A, D, and C; and let DB be produced to meet the circle again in E, and draw AE, CE.

In the triangle AEC there are given the side AC=202 fathoms, the angle ACE (=ADE. GEOM. Sect. II. Theor. 15.) =13° 30′, and the angle CAE (=CDE) 29° 50′. Hence (by TRIGON.) we shall have AE=68·716 fathoms.

Plane figures.

In the triangle ABC, all its sides are given, and hence the angle BAC will be found=35° 35′ 54″; to this, add the angle CAE, and the sum is the angle EAB=65° 25′ 54″.

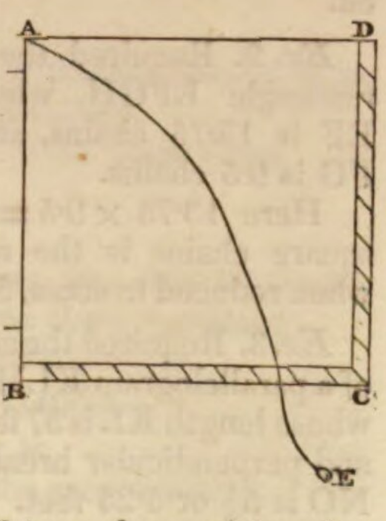
In the triangle ABE, we have given AB=106·5, AE =68·716, the angle BAE=65° 25′ 54″; hence we shall have the angle ABE=38° 43′ 41″, and the angle AEB= 75° 51′ 25″.

In the triangle ADE we have the side AE=68·716, the angle ADE=13° 30′, and the angle AED=75° 51′ 25″. Hence we have AD=285.43 fathoms, which is one of the distances required.

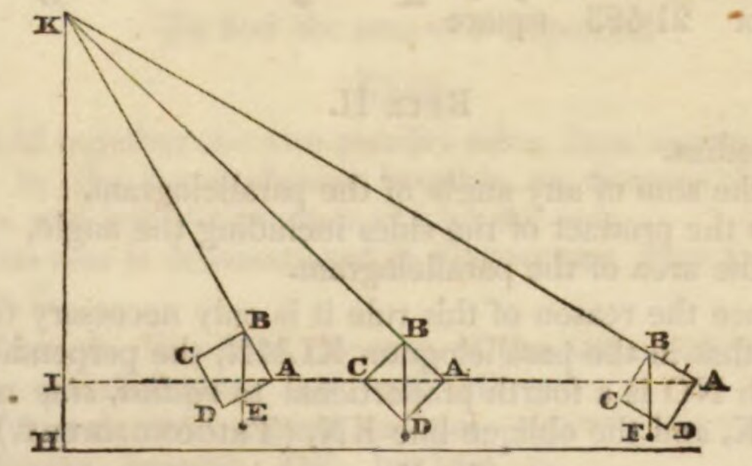
In the triangle ABD we have AB=106·5, the angle ADB, =13° 30′, the angle DAB (=ABE—ADB) 25° 13′ 45″. Hence BD, another of the distances sought, will be found =194.45 fathoms.

Lastly, In the triangle ADC, there is given AC=202, the angle ADC (=ADB+BDC) =43° 20′, the angle DCA(=DEA)=75° 15′ 25″. Hence we get DC=256·97 fathoms, which is the remaining distance sought.

There are various other instruments and methods by which the heights or distances of objects may be found. One of the most simple instruments, both in respect of its construction and application, is a square, ABCD, made of some solid material, and furnished with two sights on AB, one of its edges, and a plummet fastened to A, one of its angles, and having the two sides BC, CD, which contain the opposite angle divided into 10, or 100, or 1000 equal parts.



To measure any altitude HK with this instrument. Let it be held in such a position that



K, the top of the object may be seen through the sights on its edge AB, while its plane is perpendicular to the horizon; then the plummet will cut off from the square a triangle similar to that formed by the horizontal line AI, the vertical line IK, and the line AK drawn from the eye to the top o. the object.

If the line of the plummet pass through D the opposite angle of the square, then the height KI will be equal to AI, the distance of the eye from the vertical line to be measured. If it meet AD, the side of the square next the eye, in some point E between A and D, then the triangles ABE, AIK, being similar, and the angle ABE equal to the angle AKI, we have AE : AB :: AI : IK. Let us now suppose AD=AB to be divided into 1000 equal parts; then the length of AE will be expressed by a certain number of these parts; thus the proportion of AE to AB, and consequently that of AI to IK will be given; therefore if AI be determined by actual measurement, we may from the above proportion immediately find IK.

If again the line of the plummet meet DC the side of the

Plane figures.

square opposite to the sights, in F, then, in the similar triangles AIK, BCF, the angle AKI is equal to BFC; thus we have BC : CF :: AI : IK. Hence IK is determined as before, and in each case by adding HI the height of the eye, we shall have HK the whole height required.

SECTION II.—MENSURATION OF PLANE FIGURES.

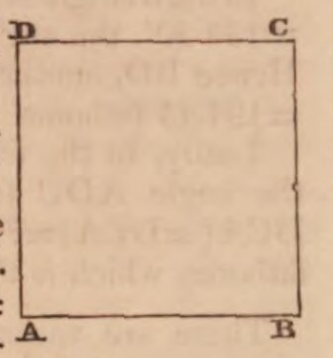
Problem I.

To find the area of a parallelogram, whether it be a square, a rectangle, a rhombus, or a rhomboid.

Rule I.

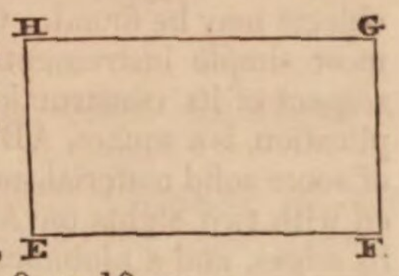
Multiply the length by the perpendicular breadth, and the product will be the area.

This rule is demonstrated in Geometry, sect. iv. theor. 5.



Ex. 1. Required the area of a square ABCD, whose side AB is $10\frac{1}{2}$ inches.

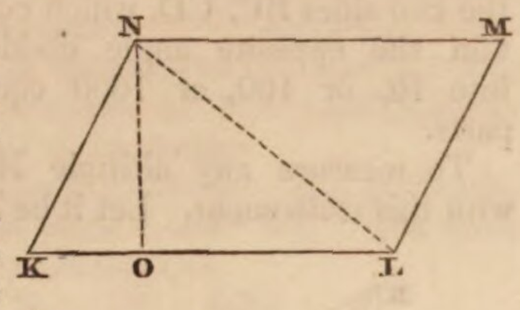
Here $10\frac{1}{2} \times 10\frac{1}{2}$ or $10{\cdot}5 \times 10{\cdot}5 = 110{\cdot}25$ square inches is the area required.



Ex. 2. Required the area of a rectangle EFGH, whose length EF is 13·75 chains, and breadth FG is 9·5 chains.

Here $13{\cdot}75 \times 9{\cdot}5 = 130{\cdot}625$ square chains is the area, which, when reduced to acres, &c. is 13 ac. 0 ro. 10 po.

Ex. 3. Required the area of a parallelogram KLMN, whose length KL is 37 feet, and perpendicular breadth NO is $5\frac{1}{4}$ or 5·25 feet.



In this example the area is $37 \times 5{\cdot}25 = 194{\cdot}25$ square feet, or 21·583 square yards.

Rule II.

As radius,
To the sine of any angle of the parallelogram,
So is the product of the sides including the angle,
To the area of the parallelogram.

To see the reason of this rule it is only necessary to observe, that in the parallelogram KLMN, the perpendicular breadth NO is a fourth proportional to *radius*, *sine* of the angle K, and the oblique line KN, (Trigonometry,) and is therefore equal to $\frac{\text{sin. K}}{\text{rad.}} \times \text{KN}$; therefore the area of the figure is $\frac{\text{sin. K}}{\text{rad.}} \times \text{KN} \times \text{KL}$, which expression is the same as the result obtained by the above rule.

Ex. Suppose the sides KL and KN are 36 feet, and 25·5 feet, and the angle K is 58°, required the area.

Here it will be convenient to employ a table of logarithms. The operation may stand thus,

log. rad.	10·00000
log. sin. 58°	9·92842
log. (36 × 25·5) = log. 36 + log. 25·5.	2·96284
log. of area	2·89126

area = 778.5 square feet.

Problem II.

Having given any two sides of a right angled triangle, to find the remaining side.

Rule.

Plane figures.

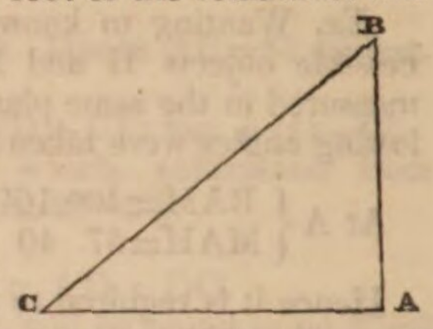
1. When the sides about the right angle are given, to find the hypothenuse.

Add together the squares of the sides about the right angle, and the square root of the sum will be the hypothenuse.

2. When the hypothenuse and one of the sides about the right angle is given, to find the other side.

From the square of the hypothenuse subtract the square of the given side, and the square root of the remainder will be the other side.

This rule is deduced from theor. 13. sect. iv. Geometry.



Ex. 1. In a right-angled triangle ABC, the sides AB and AC, about the right angle, are 33 feet and 56 feet; what is the length of the hypothenuse BC?

Here $33^2 + 56^2 = 3136 + 1089 = 4225$,
and $\sqrt{(4225)} = 65$ feet, = the hypothenuse BC.

Ex. 2. Suppose the hypothenuse BC to be 65 feet, and AB one of the sides about the right angle to be 33 feet; what is the length of AC the other side?

Here $65^2 - 33^2 = 4225 - 1089 = 3136$;
and $\sqrt{(3316)} = 56$ feet = the side AC.

Problem III.

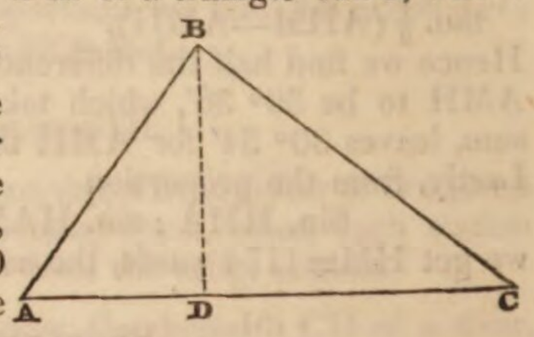
To find the area of a triangle.

Rule I.

Multiply any one of its sides by the perpendicular let fall upon it from the opposite angle, and half the product will be the area.

The truth of this rule is proved in Geometry, Part I. sect. iv. theor. 6.

Example. What is the area of a triangle ABC, whose base AC is 40, and perpendicular BD is 14·52 chains?



The product of the base by the perpendicular, or $40 \times 14{\cdot}52$, is 580·8 square chains, the half of which, or 290·4 sq. ch. = 29 ac. 0 r. 6·4 po. is the area of the triangle.

Rule II.

As radius,
To the sine of any angle of a triangle,
So is the product of the sides including the angle,
To twice the area of the triangle.

This rule follows immediately from the second rule of Prob. I., by considering that the triangle KNL is half the parallelogram KNML.

Example. What is the area of a triangle ABC, whose two sides AB and AC are 30 and 40, and the included angle A is 28° 57′?

Operation by Logarithms.

log. rad.	10·00000
log. (30 × 40) = log. 30 + log. 40.	3·07918
log. sin. 28° 57′	9·68489
log. of twice area	2·76407

twice area = 580·85
area 290·42

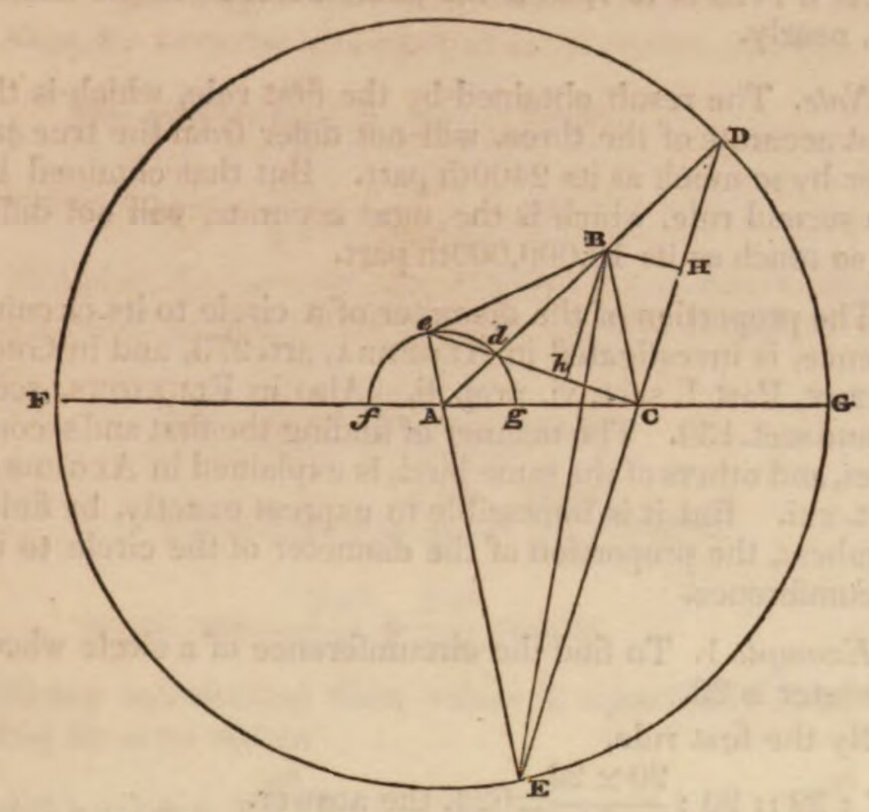
Rule III.

When the three sides are given, add together the three sides, and take half the sum. Next, subtract each side severally from the said half sum, thus obtaining three remain-

Plane figures.

ders. Lastly, multiply the said half sum, and those three remainders all together, and extract the square root of the last product for the area of the triangle.

This practical rule is deduced from the following geometrical theorem. *The area of a triangle is a mean proportional between two rectangles, one of which is contained by half the perimeter of the triangle, and the excess of half the perimeter above any one of its sides; and the other is contained by the excesses of half the perimeter above each of the other two sides.* As this theorem is not only remarkable, but also of great utility in mensuration, we shall here give its demonstration.



Let ABC then be any triangle; produce AB, any one of its sides, and take BD and B*d*, each equal to BC; join CD and C*d*, and through A draw a line parallel to BC, meeting CD and C*d* produced in E and *e*; thus the angle AED will be equal to the angle BCD, (Geometry, Part I. sect. i. theor. 21), that is, to the angle BDC or ADC, (sect. i. theor. 11); and hence AE=AD, (sect. i. theor. 12); and in like manner, because the angle A*ed* is equal to the angle BC*d*, that is, to the angle B*d*C, or A*de*, therefore A*e*=A*d*.

On A as a centre, at the distance AD or AE, describe a circle meeting AC in F and G; and on the same centre, with the distance A*d* or A*e*, describe another circle meeting AC in *f* and *g*, and draw BH and B*h* perpendicular to CD and C*d*. Then, because BD, BC, B*d* are equal, the point C is in the circumference of a circle, of which D*d* is the diameter, therefore CD and C*d* are bisected at H and *h*, (sect. ii. theor. 6), and the angle DC*d* is a right angle, (sect. ii. theor. 17), and hence the figure CHB*h* is a rectangle, so that B*h*=CH=$\frac{1}{2}$ CD, and BH=C*h*=$\frac{1}{2}$ C*d*.

Join BE, and B*e*, then the triangle BAC is equal to each of the triangles BEC, B*e*C, (sect. iv. theor. 2, cor. 2); but the triangle BEC is equal to $\frac{1}{2}$ EC × BH, (sect. iv. theor. 2), that is, to $\frac{1}{4}$ EC × C*d*; and in like manner the triangle B*e*C is equal to $\frac{1}{2}$ *e* C × B*h*, that is, to $\frac{1}{4}$ *e* C × CD, therefore the triangle ABC is equal to $\frac{1}{4}$ EC × C*d*, and also to $\frac{1}{4}$ *e*C × CD.

Now since CD : C*d* :: CE × CD : CE × C*d* } sect. iv.
and also CD : C*d* :: C*e* × CD : C*e* × C*d* } theor. 3.

Therefore CE × CD : CE × C*d* :: C*e* × CD : C*e* × C*d*; that is, because CE × CD=FC × CG, and C*e* × C*d*=*f*C × C*g*, (sect. iv. corollaries to theor. 28 and 29).

FC × CG : CE × C*d* :: C*e* × CD : *f*C × C*g*;

which last proportion (by taking one-fourth of each of its terms, and substituting the triangle ABC for its equivalent values $\frac{1}{4}$ CE × C*d* and $\frac{1}{4}$ C*e* × CD) gives us

$\frac{1}{2}$ FC × $\frac{1}{2}$ CG : *trian.* ABC :: *trian.* ABC : $\frac{1}{2}$ *f*C × $\frac{1}{2}$ C*g*.

Now, if it be considered that the radius of the circle *gde* is AB—BC, it will readily appear that, putting 2 *s* for the perimeter of the triangle ABC, we have

FC (=AB+ BC + AC) = 2 *s*
CG (=AB+ BC — AC) = 2 *s*—2 AC,
*f*C (=AC+ { AB—BC }) = 2 *s*—2 BC,
*g*C (=AC— { AB—BC }) = 2 *s*—2 AB.

Put now *a*, *b*, *c* for the sides AC, BC, and AB respectively, then $\frac{1}{2}$ FC=*s*, $\frac{1}{2}$ GC=*s*—*a*, $\frac{1}{2}$ *f*C=*s*—*b*, $\frac{1}{2}$ C*g*=*s*—*c*; thus the last proportion becomes

s × (*s*—*a*) : *trian.* ABC :: *trian.* ABC : (*s*—*b*) × (*s*—*c*),

which conclusion, when expressed in words at length, is evidently the proposition to be demonstrated.

And as a mean proportional between two quantities is found by taking the square root of the product, it follows that the area of the triangle ABC, which is a mean between *s* × (*s*—*a*) and (*s*—*b*) × (*s*—*c*), is equal to

$$\sqrt{\{ s \times (s-a) \times (s-b) \times (s-c) \}}$$

which formula, when expressed in words at length, gives the preceding rule.

Example. Required the area of a triangle whose three sides are 24, 36, and 48 chains respectively.

Here 24+36+48=108=the sum of the three sides,

And $\frac{108}{2}$ =54=half that sum;

Also 54—24=30, the first remainder; 54—36=18, the second remainder; and 54—48=6, the third remainder.

The product of the half sum and remainders is

54 × 30 × 18 × 6=174960.

And the square root of this product is

$\sqrt{(174960)}$=418·28 sq. ch. the area required.

Problem IV.

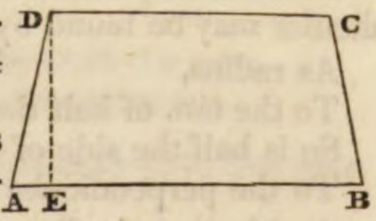
To find the area of a trapezoid.

Rule.

Add together the two parallel sides, then multiply their sum by the perpendicular breadth, or distance between them, and half the product will be the area.

This rule is demonstrated in Geometry, Part I. sect. iv. theor. 7.

Example. Required the area of the trapezoid AB CD, whose parallel sides AB and DC are 7·5 and 12·25 chains and perpendicular breadth DE is 15·4 chains.



The sum of the parallel sides is 7·5+12·25=19·75; which multiplied by the breadth, is

19·75 × 15·4=304·15;

and half this product is

$\frac{304 \cdot 15}{2}$ =152·075 sq. ch.=15 ac. 33·2 po. the area required.

Problem V.

To find the area of any trapezium.

Rule.

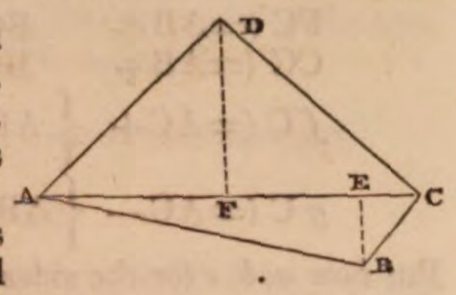
Divide the trapezium into two triangles by a diagonal, then find the areas of these triangles, and add them together.

Note. If two perpendiculars be let fall on either diagonal from the other two opposite angles, the sum of these per-

Plane figures.

pendiculars being multiplied by the diagonal, half the product will be the area of the trapezium. The reason of this rule is sufficiently obvious.

Example. In the trapezium ABCD the diagonal AC is 42, and the two perpendiculars BE, DF are 16 and 18: What is its area?



Here the sum of the perp. is 16+18=34, which multiplied by 42, and divided by 2, gives

$$\frac{34\times 42}{2}=714,$$ the area.

Problem VI.

To find the area of an irregular polygon.

Rule.

Draw diagonals dividing the proposed polygon into trapeziums and triangles; then find the areas of all these separately, and add them together for the content of the whole polygon. The reason of this rule, and the manner of applying it, are sufficiently obvious.

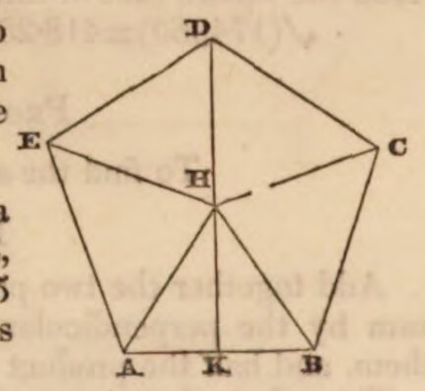
Problem VII.

To find the area of a regular polygon.

Rule.

Multiply the perimeter of the polygon, or sum of its sides, by the perpendicular drawn from its centre on one of its sides, and take half the product for the area.

This rule is only in effect resolving the polygon into as many triangles as it has sides, by drawing lines from its centre to all its angles, then taking the sum of their areas for the area of the figure.



Example. Required the area of a regular pentagon ABCDE, whose side AB or BC, &c., is 25 feet, and perpendicular HK is 17·2 feet.

Here $25\times 5=125=$the perimeter,
And $125=17\cdot 2=2150$,
And its half $1075=$the area required.

Note. If only the side of the polygon be given, its perpendicular may be found by the following proportion:

As radius,
To the tan. of half the angle of the polygon,
So is half the side of the polygon,
To the perpendicular.

And here, as well as in all other trigonometrical calculations, we may employ a table of logarithmic sines and tangents.

The angle of the polygon, that is, the angle contained by any two of its adjacent sides, will be found from this theorem. *The sum of all its interior angles is equal to twice as many right angles, wanting four, as it has sides,* which is demonstrated in Geometry, Part I. sect. i. theor. 25.

Problem VIII.

To find the diameter and circumference of a circle, the one from the other.

Rule I.

As 7 is to 22, so is the diameter to the circumference, nearly.

As 22 is to 7, so is the circumference to the diameter, nearly. Plane figures.

Rule II.

As 113 is to 355, so is the diameter to the circumference, nearly.

As 355 is to 113, so is the circumference to the diameter, nearly.

Rule III.

As 1 is to 3·1416, so is the diameter to the circumference, nearly.

As 3·1416 is to 1, so is the circumference to the diameter, nearly.

Note. The result obtained by the first rule, which is the least accurate of the three, will not differ from the true answer by so much as its 2400th part. But that obtained by the second rule, which is the most accurate, will not differ by so much as its 10,000,000th part.

The proportion of the diameter of a circle to its circumference, is investigated in Algebra, art. 273, and in Geometry, Part I. sect. vi. prop. 6. Also in Fluxions, sect. 38 and sect. 139. The manner of finding the first and second rules, and others of the same kind, is explained in Algebra, sect. xxi. But it is impossible to express exactly, by finite numbers, the proportion of the diameter of the circle to its circumference.

Example 1. To find the circumference of a circle whose diameter is 20.

By the first rule,

$$7 : 22 :: 20 : \frac{20\times 22}{7}=62\tfrac{6}{7}.$$ the answer.

Or by the third rule, $3\cdot 1416\times 20=62\cdot 832$ the answer.

Ex. 2. The circumference of a circle is 10 feet, what is its diameter?

By the second rule,

$$355 : 113 :: 10 : \frac{113\times 10}{355}=3\cdot 1831$$ the answer.

Problem IX.

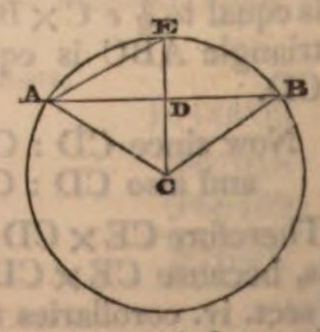
To find the length of any arch of a circle.

Rule I.

As 180 is to the number of degrees in the arch, so is 3·1416 times the radius to its length.

To see the reason of this rule it is only necessary to consider, that 3·1416 times the radius is (by last rule) equal to half the circumference, or to an arch of 180°, and that the length of an arch is proportional to the number of degrees it contains.

Example. Required the length of the arch AEB, whose chord AB is 6, the radius AC or CB being 9. Draw CD perpendicular to the chord, then CD will bisect the chord in D, and the arch in E. Now in the right-angled triangle ACD, there is given the hypothenuse AC=9, and the side AD=3; hence, by trigonometry, the angle ACE will be found to contain $19^\circ\ 28'\ \frac{5}{10}=19\cdot 471$ degrees. The double of this, or 38·942, is the number of degrees in the whole arch AEB. Then, by the rule,



$$180 : 38\cdot 942 :: 9\times 3\cdot 1416 : \frac{9\times 3\cdot 1416\times 38\cdot 942}{180}=6\cdot 11701$$

the answer.

Plane figures.

Rule II.

As six times the distance of any chord from the centre together with nine times the radius of the circle, is to that distance together with fourteen times the radius; so is the chord to the arc nearly.

The investigation of this rule is as follows:

Let a denote any arc of a circle of which the radius=1. Putting A, B, C for indeterminate quantities, assume

$$\frac{1+\text{A cos. } a}{\text{B}+\text{C cos. } a}=\frac{a}{\text{sin. } a}.$$

Then, observing that sin. a cos. $a=\frac{1}{2}$ sin. 2 a, we have

$$\text{sin. } a+\tfrac{1}{2}\text{ A sin. } 2a=a\text{ B}+a\text{ C, cos. } a. \quad (1.)$$

Now, by formulae investigated in Algebra, art. 286,

$$\text{Sin. } a=a-\frac{a^3}{1\cdot2\cdot3}+\frac{a^5}{1\cdot2\cdot3\cdot4\cdot5}-\&c.$$

$$\text{Cos. } a=1-\frac{a^2}{1\cdot2}+\frac{a^4}{1\cdot2\cdot3\cdot4}-\&c.$$

Therefore we have for sin. a, $\frac{1}{2}$ sin. 2 a, a cos. a; these approximate values, which include the fifth power of the arc,

$$\text{Sin. } a=a-\frac{a^3}{6}+\frac{a^5}{120}\text{ nearly,}$$

$$\tfrac{1}{2}\text{ sin. } 2a=a-\frac{4a^3}{6}+\frac{16a^5}{120}\text{ nearly,}$$

$$a\text{ cos. } a=a-\frac{3a^3}{6}+\frac{5a^5}{120}\text{ nearly.}$$

Hence substituting these values in equation (1.) and dividing by a we obtain

$$(1+\text{A})-(1+4\text{ A})\frac{a^2}{6}+(1+16\text{ A})\frac{a^4}{120}=\text{B}+\text{C}-3\text{ C}\frac{a^2}{6}+5\text{ C}\frac{a^4}{120}.$$

Making now the coefficients of like terms on each side of this equation equal, we have

$$1+\text{A}=\text{B}+\text{C},\ 1+4\text{ A}=3\text{ C},\ 1+16\text{ A}=5\text{ C};$$

and hence, $\text{A}=\frac{1}{14}$, $\text{B}=\frac{9}{14}$, $\text{C}=\frac{6}{14}$.

These values being substituted for A, B, C in the assumed equation, the result after reduction is

$$\frac{14+\text{cos. } a}{9+6\text{ cos. } a}=\frac{a}{\text{sin. } a}.$$

Hence the rule.

Ex. 1. Required the length of $\frac{1}{6}$th of the circumference of a circle whose radius is 10?

In this case the chord AB is equal to the radius AC=10; and the perpendicular $\text{CD}=\sqrt{(\text{CA}^2-\text{AB}^2)}=\sqrt{(100-25)}=\sqrt{75}=8.660254$: hence 6 CD+9 AC=141·961524, and CD+14 AC=148·660254. We now state this proportion,

141·961524 : 148·660254 :: 10 : 10·47187=arc AEB.

This is a near approximation to the length of the arc: its true value is 10·471976, &c.

Ex. 2. It is known that an arc of 57° 17′ 44″·8 is very nearly equal to the radius. Now, let it be proposed to find its approximate length by the formula, the radius being supposed equal to 1 mile.

In this case by the Trigonometrical Tables the chord =·958851: its distance from the centre=·8775826. Therefore the proportion is

14·2654956 : 14·8775826=·958851 : ·9999922.

The error of the approximation is ·0000078 of a mile, which is equal to about half an inch.

Problem X.

Plane figures.

To find a straight line nearly equal to a given arc of a circle.

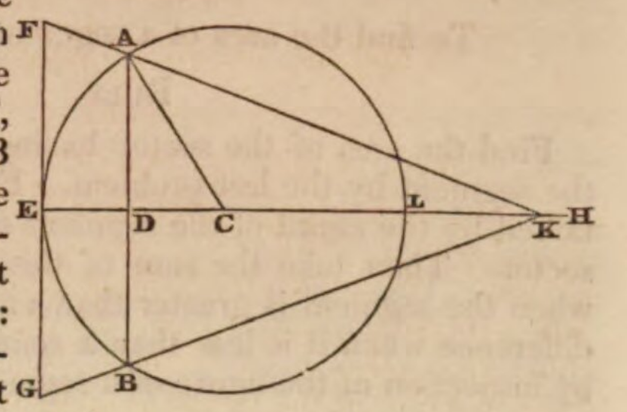
The formula $\frac{14+\text{cos. } a}{9+6\text{ cos. } a}=\frac{a}{\text{sin. } a}$ may be put under this form

$$\frac{15-(1-\text{cos. } a)}{10+5\text{ cos. } a-(1-\text{cos. } a)}=\frac{a}{\text{sin. } a}.$$

$$\text{Or, } \frac{3-\frac{1}{5}\text{ ver. sin. } a}{2+\text{cos. } a-\frac{1}{5}\text{ ver. sin. } a}=\frac{a}{\text{sin. } a}.$$

Hence we obtain the following simple geometrical construction for finding a straight line nearly equal to a given arc of a circle:

In DL produced take LH equal to the radius, and HK from H towards the centre equal to one fifth part of the versed sine DE: From K draw KF, KG through A and B the extremities of the arc AB to meet the tangent at the middle point of the arc in F and G: The intercepted portion FG of the tangent is equal to the arc AB nearly.



Problem XI.

To find the area of a circle.

Rule I.

Multiply half the circumference by half the diameter, and the product will be the area.

Rule II.

Multiply the square of the diameter by ·7854, and the product will be the area.

The first of these rules has been demonstrated in Geometry, sect. vi. prop. 3. And the second rule is deduced from the first, as follows. It appears from prop. 6. sect. vi. Geometry, that the diameter of a circle being unity, its circumference is 3·1416 nearly; therefore, by the first rule, its area is $1\times3\cdot1416\div4=\cdot7854$. But circles are to one another as the squares of their diameters, (prop. 4.) therefore, putting d for the diameter of any circle, $1:d^2::\cdot7854:\cdot7854\,d^2$=the area of the circle whose diameter is d.

Example. What is the area of a circle whose diameter is 7.

By the second rule $7\times7\times\cdot7854=38\cdot4846$ the area.

By the first rule $7\times3\cdot1416$=the circumference.

Then $\frac{7\times3\cdot1416\times7}{4}=7\times7\times\cdot7854=38\cdot4846$ the area, the same as before.

Problem XII.

To find the area of any sector of a circle.

Rule I.

Multiply the radius by half the arch of the sector, and the product will be the area, as in the whole circle.

Rule II.

As 360 is to the degrees in the arc of the sector, so is the area of the whole circle to the area of the sector.

The first of these rules follows easily from the rule for the whole area, by considering that the whole circumference is to the arch of the sector, as the whole area to the area of the sector, that is,

Plane figures.

circum. : arch of sect. :: rad. $\times \frac{1}{2}$ circum. : area of sect.
Hence area of sect. = rad. $\times \frac{1}{2}$ arch of sect.

The second rule is too obvious to need any formal proof.

Example. To find the area of a circular sector ACB whose arch AEB contains 18 degrees, the diameter being 3 feet. (See fig. to prob. ix.)

1. By the first rule.

First $3{\cdot}1416 \times 3 = 9{\cdot}4248$ the circum.
And $360 : 18 :: 9{\cdot}4248 : {\cdot}47124$ the arch of sect.
Then $\cdot47124 \times 3 \div 4 = {\cdot}35343$ the area.

2. By the second rule.

First $\cdot7854 \times 3^2 = 7{\cdot}0686$ the area of the circle.
Then $360 : 18 :: 7{\cdot}0686 : {\cdot}35343$ the area.

Problem XIII.

To find the area of a segment of a circle.

Rule.

Find the area of the sector having the same arch with the segment by the last problem. Find also the area contained by the chord of the segment and the two radii of the sector. Then take the sum of these two for the answer when the segment is greater than a semicircle, or take their difference when it is less than a semicircle. As is evident by inspection of the figure of a segment. (Fig. to prob. ix.)

Example. To find the area of the segment AEBDA, its chord AB being 12, and the radius AC or BC 10.

First, as AC : AD :: rad. : sin. $36° 52'\frac{1}{2} = 36{\cdot}87$ degrees, the degrees in the angle ACE or arch AE. And their double or $73{\cdot}74$ = the degrees in the whole arch AEB.

Now $\cdot7854 \times 400 = 314{\cdot}16$ the area of the whole circle.
Therefore $360° : 73{\cdot}74 :: 314{\cdot}16 : 64{\cdot}3504$ = area of the sector CAEB.

Again $\surd (CA^2 - AD^2) = \surd (100 - 36) = \surd 64 = 8 =$ DC.

Therefore $AD \times DC = 6 \times 8 = 48$ = area of the triangle.
Hence sector ACBA — triangle ACB = $16{\cdot}3504$ the area of seg. AEBDA.

Problem XIV.

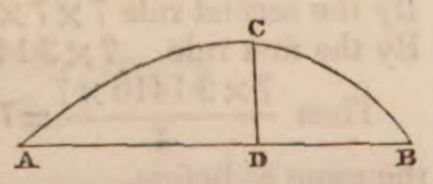
To find the area of any segment of a parabola, that is the space included by any arch of a parabola, and the straight line joining its extremities.

Rule.

Multiply the base of the segment by its height, and take $\frac{2}{3}$ of the product for the area.

This rule is demonstrated in Conic Sections, part iv. sect. iii. prop. 2.

Example. The base AB of a parabolic segment ACB is 10, and its altitude CD, (that is, the greatest line that can be drawn in the segment perpendicular to the base AB) is 4: What is its area?



Here $10 \times 4 \times \frac{2}{3} = \frac{80}{3} = 26\frac{2}{3}$ the area.

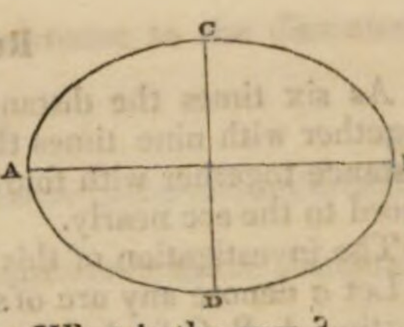
Problem XV.

To find the area of an ellipse.

Rule.

Multiply the product of the two axes by the number $\cdot7854$ for the area of the ellipse.

For the area of an ellipse is equal to the area of a circle whose diameter is a mean proportional between the axes of the ellipse, (as is easily deduced from Conic Sections, cor. i. prop. 3. sect. iii. part iv.) that is, to the area of a circle, the square of whose diameter is equal to the product of the axes. But by prob. x. the area of a circle is equal to the square of the diameter multiplied by $\cdot7854$; therefore the area of an ellipse is equal to the product of the axes multiplied by the same number $\cdot7854$.



Plane figures.

Example. If the axes of an ellipse, ABCD, be 35 and 25. What is the area?

$35 \times 25 \times \cdot7854 = 687{\cdot}225$ the area.

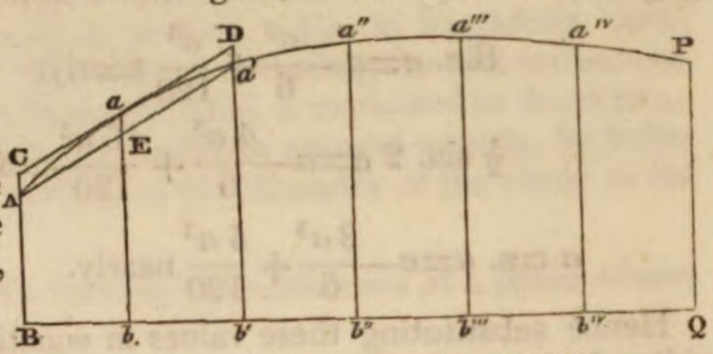
Note. As to hyperbolic areas, the reader will find formulas for their exact mensuration in Fluxions, § 156. Ex. 4 and 5.

Problem XVI.

To find nearly the area of a figure bounded by any curve line A a a' a'', &c. P, the straight line BQ, and AB, PQ two other straight lines drawn from the extremities of the curve perpendicular to BQ.

Rule.

Let BQ, the base of the figure, be divided into any even number of equal parts by the perpendiculars $b\,a$, $b'\,a'$, $b''\,a''$, &c. which meet the curve in the points a, a', a'', &c.



Let F and L denote the first and last perpendiculars AB and PQ.

Let E denote the sum of all the remaining even perpendiculars, viz. $a\,b$, $a''\,b''$, $a^{iv}\,b^{iv}$, the second, fourth, sixth, &c.

Let R denote the sum of the remaining perpendiculars, viz. $a'\,b'$, $a'''\,b'''$, &c.

And put D for B b, or bb', &c. the common distance between the perpendiculars.

Then the area of the figure will be nearly equal to

$$\tfrac{1}{3}D \times (F + L + 4E + 2R);$$

and the approximation will be so much the more accurate according as the number of perpendiculars is the greater.

Demonstration. Join the tops of the first and third perpendiculars by the line A a' meeting the second perpendicular in E, and draw CD through a so as to form the parallelogram A a' DC; then the space bounded by the curve line A a a' and the three straight lines AB, B b', b' a' will be made up of the trapezoid AB b' a', and the space bounded by the arch A a a' and its chord A a'. Now if the arch A a a' be small, this last space will be nearly two thirds of the parallelogram AD, for it will be nearly equal to the area contained by the straight line A a', and an arch of a parabola passing through the points A, a, a', and having $a\,b$ for a diameter, which area is $\frac{2}{3}$ of its circumscribing parallelogram. (Conic Sections, part iv. sect. iii. prop. 2). Therefore the space A $a\,a'\,b'$ BA will be nearly equal to the sum of the trapezoid AB $b'\,a'$ and $\frac{2}{3}$ of the parallelogram AD, which sum is evidently equal to $\frac{1}{3}$ of the trapezoid AB $b'\,a'$, together with $\frac{2}{3}$ of the trapezoid CB b' D. Now the area of the trapezoid AB $b'\,a'$ is $\frac{AB + a'b'}{2} \times B\,b'$ (Geometry, sect. iv. theor. 7.) $= \frac{AB + a'b'}{2} \times 2B\,b$; and in like manner the area of the trapezoid CB b'D is $\frac{CB + Db'}{2} \times B\,b' = ab \times 2B\,b$; therefore the area of the figure A $a\,a'\,b'$ B is nearly $\frac{1}{3} \times \frac{AB + a'b'}{2} \times 2B\,b + \frac{2}{3} \times ab \times 2B\,b = \frac{1}{3}(AB + 4ab + a'\,b')\,B\,b$.

Plane figures.

In the very same way it may be shewn that the area of the figure $a'\ a''\ a'''\ b'''\ b'$ is nearly

$$\tfrac{1}{3}(a'\ b'+4\ a''\ b''+a'''\ b''')\times Bb,$$

and that the area of the figure $a'''\ a^{iv}\ PQb'''$ is nearly

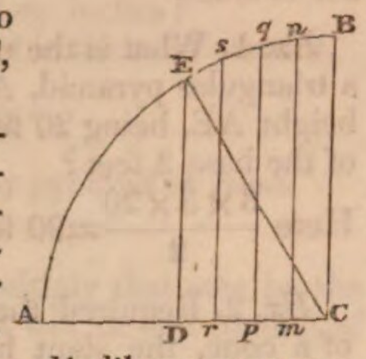
$$\tfrac{1}{3}(a'''\ b'''+4a^{iv}\ b^{iv}+PQ)\times Bb.$$

Therefore, the area of the whole figure bounded by the curve line AP, and the straight lines AB, BQ, QP, is nearly equal to the sum of these three expressions, namely, to

$$\tfrac{1}{3}Bb\times\left\{\begin{array}{c}AB+PQ\\+4(a\ b+a''\ b''+a^{iv}\ b^{iv})\\+2(a'\ b'+a'''\ b''')\end{array}\right\}$$

as was to be demonstrated.

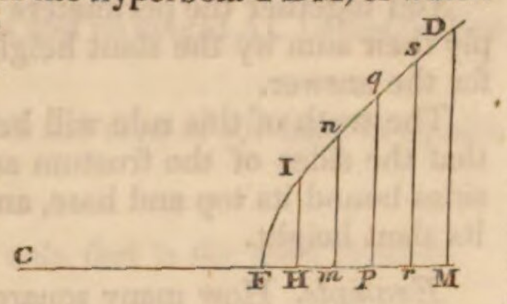
Example 1. Let it be required to find the area of the quadrant ABC, whereof the radius AC=1.



Let AC be bisected by the perpendicular DE, and let CD be divided into four equal parts by the perpendiculars *mn*, *pq*, *rs*. Now because CA=1, therefore CD=$\frac{1}{2}$, C*r* =$\frac{3}{8}$, C*p*=$\frac{1}{4}$, C*m*=$\frac{1}{8}$. Hence DE= $\sqrt{(EC^2-CD^2)}=\sqrt{(1-\frac{1}{4})}=\frac{1}{2}\sqrt{3}$; and in like manner *rs*= $\frac{1}{8}\sqrt{55}$, *pq*=$\frac{1}{4}\sqrt{15}$, *mn*=$\frac{1}{8}\sqrt{63}$. Therefore,

F+L=1+$\frac{1}{2}\sqrt{3}$	= 1·8660
4 E=$\frac{1}{2}\sqrt{55}+\frac{1}{2}\sqrt{63}$	= 7·6767
2 R=$\frac{1}{2}\sqrt{15}$	= 1·9365
The sum	11·4792
Multiply by $\frac{1}{3}$ D=	$\frac{1}{\sigma^4}$
The product is	.4783
Subtract the triangle CDE	.2165
There remains the sector CBE=	.2618
The triple of which is the quadrant ABC=	.7854

Ex. 2. To find the area of the hyperbola FDM, of which the absciss FM=10, the semiordinate MD=12, and semitransverse CF=15.



Let FM be divided into five equal parts by the semiordinates HI, *mn*, *pq*, *rs*. Thus CH=17, C*m*=19, C*p* =21, C*r*=23, CM=25. Now, since from the nature of the curve, $\sqrt{(CM^2-CF^2)}$: MD :: $\sqrt{(CH^2-CF^2)}$: HI (Conic Sections, part iii. prop. 22. and Geom. part i. sect. iv. theor. 12,) that is, in numbers, 20 : 12 :: 8 : HI, therefore HI=$\frac{24}{5}$. In like manner we find *mn*=$\frac{6}{5}\sqrt{34}$, *pq*=$\frac{18}{5}\sqrt{6}$, and *rs*=$\frac{12}{5}$ $\sqrt{19}$. Therefore

F+L(=HI+MD)	= 16·8
4E(=4*mn*+4*rs*)	= 68·8399
2R(=2*pq*)	= 17·6363

The figure HIDM = 103·2762 × $\frac{2}{3}$=68·8508. to which adding FIH, considered as a portion of a parabola, we have 75·245 for the area of the hyperbola.

OF LAND-SURVEYING.

The instruments most commonly employed in land-surveying, are the Chain, the Plane Table, and Cross.

A statute acre of land being 160 square poles, the chain is made four poles, or sixty-six feet in length, that ten square chains, or 100,000 square links) may be equal to an acre. Hence each link is 7·92 inches in length.

The plane table is used for drawing a plan of a field, and taking such angles as are necessary to calculate its area. It is of a rectangular form, and is surrounded by a moveable frame, by means of which a sheet of paper may be fixed to its surface. It is furnished with an index by which a line may be drawn on the paper in the direction of any object in the field, and with scales of equal parts by which such lines may be made proportional to the distances of the objects from the plane table when measured by the chain, and its frame is divided into degrees for observing angles. Plane figures.

The cross consists of two pair of sights set at right angles to each other upon a staff having a pike at the bottom to stick into the ground. Its use is to determine the points where a perpendicular drawn from any object to a line will meet that line; and this is effected by finding by trials a point in the line, such that the cross being fixed over it so that one pair of the sights may be in the direction of the line, the object from which the perpendicular is to be drawn may be seen through the other pair; then the point thus found will be the bottom of the perpendicular, as is evident.

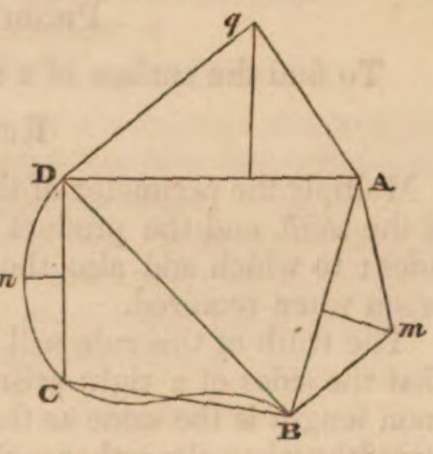
A theodolite may also be applied with great advantage to land-surveying, more especially when the ground to be measured is of great extent.

In addition to these, there are other instruments employed in surveying, as the perambulator, which is used for measuring roads and other great distances. Levels, with telescopic or other sights, which are used to determine how much one place is higher or lower than another. An ofsett-staff for measuring the ofsets and other short distances. Ten small arrows, or rods of iron or wood, which are used to mark the end of every chain length. Pickets or staves with flags to be set up as marks or objects of direction; and, lastly, scales, compasses, &c. for protracting and measuring the plan upon paper.

The observations and measurements are to be regularly entered as they are taken, in a book which is called the field book, and which serves as a register of all that is done or occurs in the course of the survey.

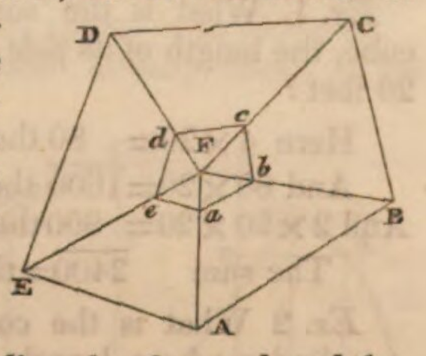
To Measure a Field by the Chain.

Let A*m*BC*n*D*q* represent a field to be measured. Let it be resolved into the triangles A*m*B, ABD, BCD, A*q*D. Let all the sides of the large triangles ABD, BCD, and the perpendiculars of the small ones A*m*B, A*q*D from their vertices *m*, *q*, be measured by the chain, and the areas calculated by the rules delivered in this section, and their amount is the area of the whole. But if, on account of the curvature of its sides the field cannot be wholly resolved into triangles, then, either a straight line may be drawn over the curve side, so that the parts cut off from the field, and those added to it may be nearly equal; or, without going beyond the bounds of the field, the curvilineal spaces may be measured by the rule given in prob. xvi. of this section.



To Measure a Field with the Plane Table.

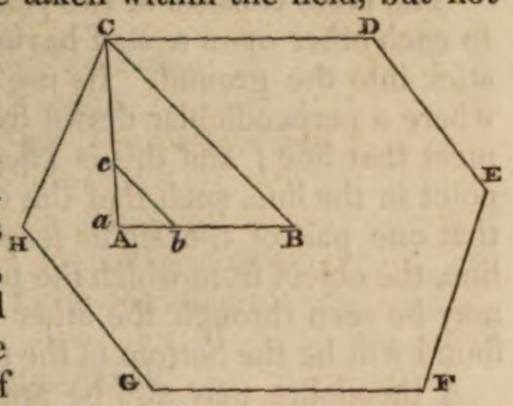
Let the plane table be fixed at F, about the middle of the field ABCDE, and its distances FA, FB, FC, &c. from the several corners of the field measured by the chain. Let the index be directed from any point assumed on the paper to the points A, B, C, D, &c., successively, and the lines F*a*, F*b*, F*c*, &c., drawn in these directions. Let the angles contained by these lines be observed, and the lines themselves made proportional to the distances measured. Then their extremities being joined, there will be formed



Solids. a figure *a b c d e* similar to that of the field; and the area of the field may be found by calculating the areas of the several triangles of which it consists.

To Plan a Field from a given Base Line.

Let two stations A, B be taken within the field, but not in the same straight line with any of its corners; and let their distance be measured. Then the plane table being fixed at A, and the point *a* assumed on its surface directly above A, let its index be directed to B, and the straight line *a b* drawn along the side of it to represent AB. Also, let the index be directed from *a* to an object at the corner C, and an indefinite straight line drawn in that direction, and so of every other corner successively. Next, let the plane table be set at B, so that *b* may be directly over B, and *b a* in the same direction with BA, and let a straight line be drawn from *b* in the direction BC. The intersection of this line with the former, it is evident will determine the point C, and the triangle *a b c* on the paper will be similar to ABC in the field. In this manner all the other points are to be determined, and these being joined there will be an exact representation of the field.



If the angles at both stations were observed, as the distance between them is given, the area of the field might be calculated from these data, but the operation is too tedious for practice. It is usual therefore to measure such lines in the figure that has been constructed as will render the calculation easy.

SECTION III.—MENSURATION OF SOLIDS.

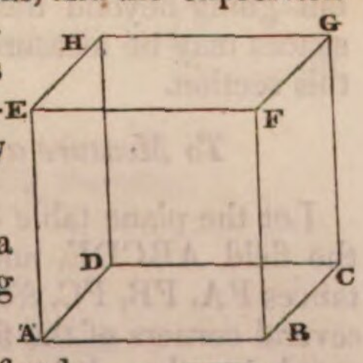
Problem I.

To find the surface of a right prism, or cylinder.

Rule.

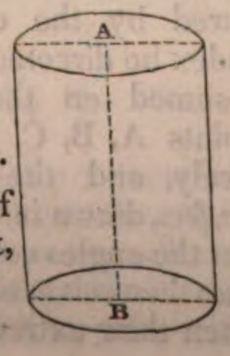
Multiply the perimeter of the end by the length or height of the solid, and the product will be the surface of all its sides; to which add also the area of the two ends of the prism when required.

The truth of this rule will be evident, if it be considered that the sides of a right prism are rectangles, whose common length is the same as the length of the solid, and their breadths taken altogether make up the perimeter of the ends of the prism. And as a cylinder may be considered as the limit of all the prisms which can be inscribed in or circumscribed about its base, so the surface of the cylinder will be the limit of the surfaces of these prisms, and the expression for that limit is evidently the product of the circular base by its height. Or a cylinder may be considered as a prism of an indefinitely great number of sides.



Ex. 1. What is the surface of a cube, the length of its side AB being 20 feet?

Here $4 \times 20 = 80$ the perim. of end.
And $80 \times 20 = \overline{1600}$ the four sides.
And $2 \times 20 \times 20 = 800$ the top and bottom.
The sum $\overline{2400}$ = the area or surface.



Ex. 2 What is the convex surface of a cylinder whose length AB is 20 feet, and the circumference of its base 3 feet?
Here $3 \times 20 = 60$ feet, the answer.

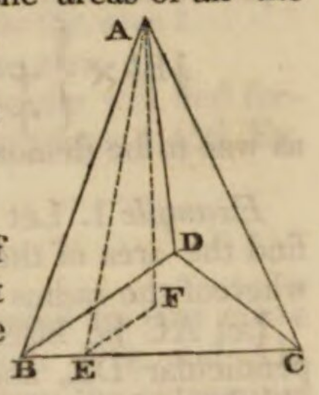
Problem II.

To find the surface of a right pyramid or cone.

Rule.

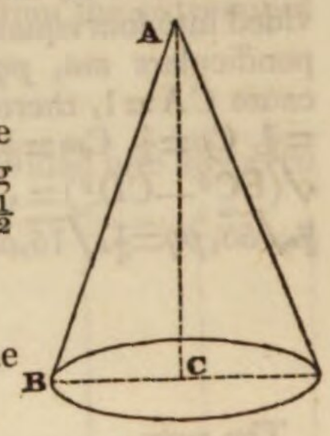
Multiply the perimeter of the base by the slant height or length of the side, and half the product will evidently be the surface of the sides, or the sum of the areas of all the triangles which form it. To which add the area of the end or base, if required.

Note. Here a cone is considered as a pyramid of an indefinitely great number of sides.



Ex. 1. What is the upright surface of a triangular pyramid, ABCD, the slant height AE, being 20 feet, and each side of the base 3 feet?

Here $\frac{3 \times 3 \times 20}{2} = 90$ feet, the surface.



Ex. 2. Required the convex surface of a cone, the slant height AB being 50 feet, and the diameter of its base $8\frac{1}{2}$ feet.

Here $8{\cdot}5 \times 3{\cdot}1416 =$ circum. of base.
And $\frac{8{\cdot}5 \times 3{\cdot}1416 \times 50}{2} = 6667{\cdot}59$, the answer.

Problem III.

To find the surface of the frustum of a right pyramid or cone, being the lower part, when the top is cut off by a plane parallel to the base.

Rule.

Add together the perimeters of the two ends, and multiply their sum by the slant height, and take half the product for the answer.

The truth of this rule will be evident if it be considered that the sides of the frustum are trapezoids, whose parallel sides bound its top and base, and whose common breadth is its slant height.

Example. How many square feet are in the surface of a frustum AG of a square pyramid, (see fig. to prob. vi.) whose slant height RE is 10 feet; also each side of the greater end AC is 3 feet 4 inches, and each side of the lesser end EG 2 feet 2 inches?

Here $3\frac{1}{3} \times 4 = 13\frac{1}{3}$ the per. of gr. end.
And $2\frac{1}{6} \times 4 = 8\frac{2}{3}$ the per. of less end.
And their sum is 22 feet.
Therefore $\frac{22 \times 10}{2} = 110$ feet, is the answer.

Problem IV.

To find the solid content of any prism or cylinder.

Rule.

Find the area of the base or end of the figure, and multiply it by the height or length, and the product will be the area.

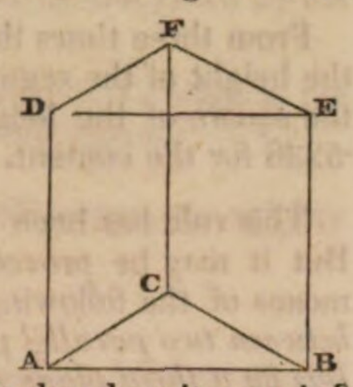
This rule follows immediately from theor. 11, and theor. 2, part ii. sect. iii. Geometry.

Ex. 1. What is the solid content of a cube AG, the length of whose sides is 24 inches?

Here $24 \times 24 = 576$ sq. inches, the area of the end.
And $576 \times 24 = 13824$ cub. inches is the solidity.

Ex. 2. Required the content of a triangular prism, whose

Solids. length AD is 20 feet, and the sides of its triangular base ABC, are 3, 4, and 5 feet.



First, the area of the triangular base is found by Rule iii. of Prob. 3, sect. ii. to be

$$\sqrt{(6\times3\times2\times1)}=6 \text{ sq. feet.}$$

Therefore $6\times20=120$ cub. feet, the solidity.

Ex. 3. The Winchester bushel is a cylinder $18\frac{1}{2}$ inches in diameter, and eight inches deep. How many cubic inches does it contain?

By prop. 10 of sect. ii. the area of its base is

$$\cdot7854\times18\cdot5^2=268\cdot803 \text{ sq. inches;}$$

Therefore $268\cdot803\times8=2150\cdot424$ is the solid content.

Problem V.

To find the solid content of any pyramid or cone.

Rule.

Find the area of the base, and multiply that area by the height, and one-third of the product will be the content of the solid.

This rule is demonstrated in Geometry, part ii. sect. ii. prop. xvii. cor. 1, and sect. iii. theor. 3.

Ex. 1. What is the content of a triangular pyramid ABCD, whose perpendicular height AF is 30 feet, and each side of its base BCD is three feet? (See fig. in prob. ii. sect. iii.)

First, the area of the base, as found by rule iii. of prob. 3, sect. ii. is

$$\sqrt{(4\cdot5\times1\cdot5\times1\cdot5\times1\cdot5)}=3\cdot89711.$$

Therefore $\frac{3\cdot89711\times30}{3}=38\cdot9711$ cub. feet is the solid content.

Ex. 2. What is the solid content of a cone, the radius BC of its base being nine inches, and its height AC 15 feet? (See fig. in prob. ii. sect. iii.)

Here $\cdot7854\times\frac{3^2}{2^2}=1\cdot76715$ is the area of the base in square feet.

And $\frac{1\cdot76715\times15}{3}=8\cdot8357$ cub. feet is the solid content.

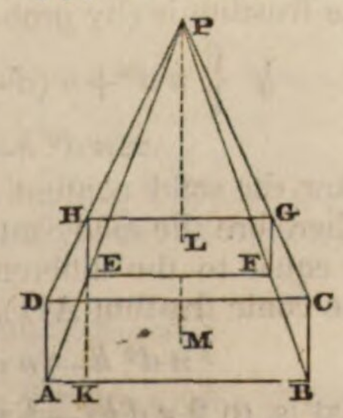
Problem VI.

To find the solidity of the frustum of a cone or pyramid.

Rule.

Add into one sum the areas of the two ends, and the mean proportional between them, that is, the square root of their product, and one-third of that sum will be a mean area, which being multiplied by the perpendicular height or length of the frustum will give the content.

Demonstration. Let PABCD be any pyramid, and AG a frustum of it contained between ABCD its base, and EFGH, a plane parallel to the base. Put a for the side of a square equal to AC the base of the frustum; b for the side of a square equal to EG its top; h for LM the height of the frustum, and c for PL the height of the part of the pyramid above the frustum. Then a^2 is the area of the base of the frustum; b^2 is the area of its top; $\frac{1}{3}a^2(h+c)$ is the solid content of the whole pyramid, (Geom. part ii. sect. ii. theor. 17), $\frac{1}{3}b^2c$ is the content of its upper part; and therefore



$$\frac{1}{3}\left\{a^2(h+c)-b^2c\right\}$$

is the solid content of the frustum itself. Now the base and top of the frustum being similar figures, (Geom. part ii. sect. ii. theor. 13), their areas are to one another as the squares of AB and EF, their homologous sides, (part i. sect. iv. theor. 27). But AB : EF :: BP : PF (sect. iv. theor. 20.) :: PM : PL; therefore the area of the base of the frustum is to the area of its top as $PM^2 : PL^2$, that is, $a^2 : b^2 :: (h+c)^2 : c^2$, and consequently $a : b :: h+c : c$;

hence $a\,c=b\,h+b\,c$, and $c=\frac{b\,h}{a-b}$, and $h+c=\frac{a\,h}{a-b}$. Let these values of c and $h+c$ be now substituted in the preceding expression for the content of the frustum, and it will become by proper reduction,

$$\frac{1}{3}\,h\,\frac{a^3-b^3}{a-b}.$$

Let the numerator of the fractional part of this formula be actually divided by its denominator, and we shall obtain for the area of the frustum this more simple expression,

$$\frac{1}{3}\,h\,(a^2+a\,b+b^2),$$

which formula, when expressed in words, is the rule. And as a cone may be considered as the limit of all the pyramids that can be inscribed in it, when the number of sides is conceived indefinitely increased, it is evident that the rule will apply alike to the cone and pyramid.

Ex. 1. Required the solidity of the frustum of a hexagonal pyramid, the side of whose greater end is four feet, and that of its lesser end is three feet, and its height nine feet.

First, by prob. 7, sect. ii. the area of the base of the frustum is found to be 41·569, and the area of its lesser end 23·383 square feet. And the mean proportional between these is

$$\sqrt{(41\cdot569\times23\cdot383)}=31\cdot177.$$

Hence the mean area is

$$\frac{1}{3}(23\cdot383+41\cdot569+31\cdot177)=32\cdot043.$$

And the solid content of the frustum is

$$32\cdot043\times9=288\cdot387 \text{ cubic feet.}$$

Ex. 2. What is the solidity of the frustum of a cone, the diameter of the greater end being five feet, that of the lesser end three feet, and the altitude nine feet?

Here the area of the greater end is (by prob. 10, sect. ii.) $5^2\times\cdot7854$, and the area of the lesser end is $3^2\times\cdot7854$, and the mean proportional between them is $\sqrt{(5^2\times3^2\times\cdot7854^2)}=5\times3\times\cdot7854$; therefore the mean area is

$$\frac{\cdot7854}{3}\times(5^2+3^2+5\times3)=12\cdot8282.$$

And the content of the frustum

$$12\cdot8282\times9=115\cdot4538 \text{ cub. feet.}$$

Problem VII

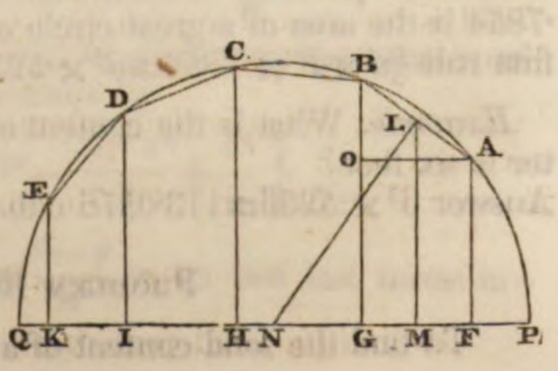
To find the surface of a sphere, or of any segment or zone of it.

Rule.

Multiply the circumference of the sphere by the height of the part required, and the product will be the curve surface, whether it be a segment, a zone, or the whole sphere.

Note. The height of the whole sphere is its diameter.

The truth of this rule has been already shown in the article Fluxions, sect. 165. It may, however, be deduced from principles more elementary, by reasoning as follows: Let PCQ be a semicircle, and AB, BC, CD, &c., several successive sides of a regular polygon inscribed in it. Con-



Solids. ceive the semicircle to revolve about the diameter PQ as an axis, then the arch ABCDE will generate a portion of the surface of a sphere, and the chords AB, BC, CD, &c., will generate the surfaces of frustums of cones; and it is easy to see that the number of chords may be so great that the surface which they generate shall differ from the surface generated by the arch ACE by a quantity which is less than any assigned quantity. Bisect AB in L, and draw AF, LM, BG, CH, &c., perpendicular to PQ. For the sake of brevity, let *circ.* AF denote the circumference of a circle whose radius is AF. Then because AF, BG, LM, are to each other respectively as *circ.* AF, *circ.* BG, *circ.* LM, (GEOM. part i. sect. vi. prop. 4. cor. i.), and because $\frac{1}{2}$ (AF + BG) = LM, therefore $\frac{1}{2}$ (*circ.* AF + *circ.* BG) = *circ.* LM. Now the area of the surface generated by the chord AB is $\frac{1}{2}$ (*circ.* AF + *circ.* BG) × AB, (prob. 3), therefore the same area is also equal to (*circ.* LM) × AB. Draw AO parallel to FG, and draw LN to the centre of the circle. Then the triangles AOB, LMN are manifestly similar; therefore AB : AO :: NL : LM :: *circ.* NL : *circ.* LM; and hence AO × *circ.* NL = AB × *circ.* LM. But this last quantity has been proved equal to the surface generated by AB, therefore the same surface is equal to AO × *circ.* NL, or to FG × *circ.* NL, that is, to the rectangle contained by FG and the circumference of a circle inscribed in the polygon. In the same way it may be shown that the surfaces generated by BC, CD, DE, are respectively equal to GH × *circ.* LN, HI × *circ.* LN, IK × *circ.* LN. Therefore the whole surface generated by the chords AB, BC, CD, DE, &c., is equal to (FG + GH + HI + IK) × *circ.* LN = FK × *circ.* LN. Conceive now the number of chords between A and E to be indefinitely increased; then, observing that the limit of the surface generated by the chords is the surface generated by the arch ABCDE, and that the limit of NL is NP, the radius of the generating circle, it follows that the spherical surface or zone generated by the arch ACE is equal to the product of the circumference of the sphere by FK the height of the zone.

Ex 1. What is the superficies of a globe whose diameter is 17 inches?

First 17 × 3·1416 = 53·4072 inches = the circum.

Then 53·4072 × 17 = 907·9224 sq. inches = 6·305 sq. feet, the answer.

Ex. 2. What is the convex surface of a segment eight inches in height cut off from the same globe?

Here 53·4072 × 8 = 427·2576 sq. inches = 2·967 sq. feet, the answer.

PROBLEM VIII.

To find the solidity of a sphere.

RULE I.

Multiply the area of a great circle of the sphere by its diameter, and take $\frac{2}{3}$ of the product for the content.

RULE II.

Multiply the cube of the diameter by the decimal ·5236 for the content.

The first of these rules is demonstrated in GEOMETRY, part i. sect. iii. theor. 6. And the second is deduced from the first, thus: put d for the diameter of the sphere, then $d^2 \times$ ·7854 is the area of a great circle of the sphere, and by the first rule $\frac{2}{3}d \times d^2 \times$ ·7854 = $d^3 \times$ ·5236 is its content.

Example. What is the content of a sphere whose diameter is six feet?

Answer $6^3 \times$ ·5236 = 113·0976 cub. feet.

PROBLEM IX.

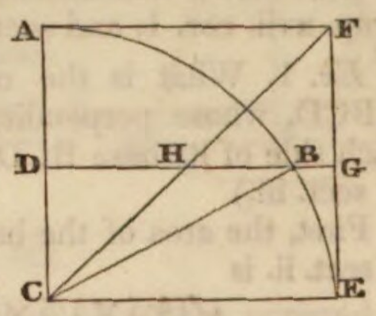
To find the solid content of a spherical segment.

RULE.

Solids. From three times the diameter of the sphere take double the height of the segment, then multiply the remainder by the square of the height, and the product by the decimal ·5236 for the content.

This rule has been investigated in FLUXIONS, sect. 163. But it may be proved in a more elementary manner by means of the following axiom. *If two solids be contained between two parallel planes, and if the sections of these solids by a third plane parallel to the other two, at any altitude, be always equal to one another, then the solids themselves are equal. Or more generally thus. If two solids between two parallel planes be such, that any sections of them by a third plane parallel to the other two have always to each other the same given ratio, then the solids themselves are to one another in that ratio.* We have given this proposition in the form of an axiom, for the sake of brevity, but its truth may be strictly demonstrated, as has been done when treating of pyramids and the sphere, in GEOMETRY, part ii. sect. ii. and iii.

Let us now suppose ABE to be a quadrant, C the centre of the circle, AFEC a square described about the quadrant, and CF the diagonal of the square. Suppose the figures to revolve about AC as an axis, then the quadrant will generate a hemisphere, the triangle ACF will generate a cone, and the square AE a cylinder. Let these three solids be cut by a plane perpendicular to the axis, and meeting the plane of the square, in the line DHBG, and join CB. Then because CDB is a right-angled triangle, a circle described with CB as a radius is equal to two circles described with CD and DB as radii. (GEOM. part i. sect. vi. prop. 4, cor. 2). But CB = DG, and since CA = AF, therefore CD = DH; therefore the circle described with the radius DG, is equal to the sum of the circles described with the radii DH, DB; that is, the section of the cylinder at any altitude, is equal to the corresponding sections of the sphere and cone taken together. Consequently, by the foregoing axiom, the cylinder is equal to the hemisphere and cone taken together, and also the segment of the cylinder between the planes AF, DG is equal to the sum of the segments of the hemisphere and cone contained between the same planes. Put 2 CE, or 2 AF, the diameter of the circle, $= d$, and AD, the height of the spherical segment, $= h$. Then AC = $\frac{1}{2}$ d and 2 CA — 2 AD = 2 CD = $d - 2h$. Let n denote the number ·7854. Then the area of the base common to the conic frustum AH, and cylinder AG, is $n d^2$, (sect. ii. prob. 10), and the area of the top of the frustum is $n (d - 2h)^2$, and the mean proportional between these areas is $n (d - 2h) d$. Therefore the solid content of the frustum is (by prob. 6 of this sect.)



$$\tfrac{1}{3} \left\{ n d^2 + n (d - 2h)^2 + n d (d - 2h) \right\} \times h.$$

$$= n d^2 h - 2 n d h^2 + \tfrac{4}{3} n h^3.$$

Now the solid content of the cylinder is $n d^2 h$: (prob. 1). Therefore the solid content of the spherical segment, (which is equal to the difference between the cylinder AG and the conic frustum AH), is equal to

$$n d^2 h - (n d^2 h - 2 n d h^2 + \tfrac{4}{3} n h^3),$$

that is, to $2 n d h^2 - \frac{4}{3} n h^3$, or to

$$\frac{2 n}{3} (3 d - 2 h) h^2,$$

which expression, if it be considered that $\frac{2 n}{3}$ or $\frac{2 \times \cdot 7854}{3}$

Solids. is equal to ·5236, is evidently the same as that given by the rule.

Example. In a sphere whose diameter is 21, what is the solidity of a segment whose height is 4·5 inches?

First $3\times21-2\times4\cdot5=54$.

Then $54\times4\cdot5\times4\cdot5\times\cdot5236=572\cdot5566$ inches, the solidity required.

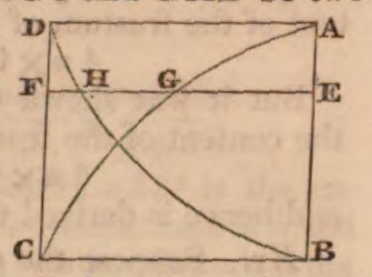
Problem X.

To find the solid content of a paraboloid, or solid, produced by the rotation of a parabola about its axis.

Rule.

Multiply the area of the base by the height, and take half the product for the content.

To demonstrate this rule, let AGC and BHD be two equal semi-parabolas lying in contrary directions, and having their vertices at the extremity of the line AB. Let AD, BC be ordinates to the curves. Complete the rectangle ABCD, and conceive it to revolve about AB as an axis; then the rectangle will generate a cylinder, the radius of whose base will be AD, and the two semi-parabolas will generate two equal paraboloids having the same base and altitude as the cylinder. Let a plane be drawn perpendicular to the axis, and let FHGE be the common section of this plane and the generating figure. Let P denote the parameter of the axis. Then since



$$EG^2=P\times AE,$$
$$\text{and } EH^2=P\times EB,$$
$$EG^2+EH^2=P\times AB=CB^2$$

Hence it appears, as in the demonstration of the preceding rule, that of the solids described by ADCB, ACB, ADB between the same parallel planes, the section of the cylinder at any altitude is equal to the corresponding sections of the paraboloids taken together. Consequently (by the axiom) the cylinder is equal to both the paraboloids taken together; hence each is half a cylinder of the same base and altitude agreeing with the rule.

The same thing is also proved in Fluxions, sect. 163.

Example. If the diameter of the base of a paraboloid be 10 and its height 12 feet, what is its content?

Here $10\times\cdot7854=7\cdot854$ the area of the base.

And $\frac{1}{2}\times7\cdot854\times12=47\cdot124$ cub. feet is the solidity.

Problem XI.

To find the solid content of a frustum of a paraboloid.

Rule.

Add together the areas of the circular ends, then multiply that sum by the height of the frustum, and take half the product for its solid content.

To prove this rule put A and a for the greater and lesser ends of the frustum, and h for its height; also let c denote the height of the portion cut off from the complete paraboloid, so as to form the frustum. Then, by the last problem, the content of the complete paraboloid is $\frac{1}{2}$ A $(h+c)$, and the content of the part cut off is $\frac{1}{2}\,a\,c$, therefore the content of the frustum is

$$\tfrac{1}{2}\left\{\text{A}\,(h+c)-a\,c\right\}=\tfrac{1}{2}\left\{\text{A}\,h+c(\text{A}-a)\right\}$$

But from the nature of the parabola, $c:h+c::a:\text{A}$; hence $\text{A}\,c=a\,h+a\,c$ and $c=\dfrac{a\,h}{\text{A}-a}$.

Let this value of c be substituted instead of it in the above expression for the content of the frustum, and it becomes

$$\tfrac{1}{2}(\text{A}\,h+a\,h)=\tfrac{1}{2}h(\text{A}+a),$$

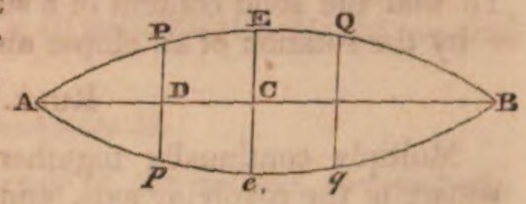
and hence is derived the rule. Solids.

Example. Required the solidity of the frustum of a paraboloid, the diameter of the greater end being 58, and that of the lesser end 30, and the height 18.

First, (by prob. 10, sect. ii.) we find the areas of the ends to be $58^2\times\cdot7854$, and $30^2\times\cdot7854$; therefore their sum is $(58^2+30^2)\times\cdot7854=4264\times\cdot7854$; and the content of the figure is $\frac{1}{2}\times4264\times\cdot7854\times18=03140\cdot5104$, the answer.

Problem XI.

To find the solid content of a parabolic spindle or solid generated by the rotation of AEB an arc of a parabola, about AB an ordinate to the axis.



Rule.

Multiply the area of the middle section by the length, and take $\frac{8}{15}$ of the product for the content of the solid.

For the investigation of this rule we must refer the reader to Fluxions, § 163. *Ex.* 4.

Example. The length of the parabolic spindle AEB*e*A is 60, and the middle diameter E *e* 34; what is the solidity?

Here $34^2\times\cdot7854$ is area of the middle section.

Therefore $34^2\times\cdot7854\times60\times\frac{8}{15}=29053\cdot5168$ is the solidity required.

Problem XII.

To find the solid content of the frustum of a parabolic spindle, one of the ends of the frustum passing through the centre of the spindle.

Rule.

Add into one sum eight times the square of the diameter of the greater end, and three times the square of the lesser end, and four times the product of the diameters; multiply the sum by the length, and the product multiplied by ·05236, or $\frac{1}{15}$ of ·7854, will be the content.

For, referring the reader to Fluxions, § 163. *Ex.* 4. as before, and substituting h for $\text{AC}=\frac{1}{2}\,b$, but, in other respects, retaining the figure and notation, we have this general expression for the segment AP p,

$$\frac{\pi\,x^3}{a^2}\left(\frac{4\,h^2}{3}-h\,x+\frac{x^2}{5}\right),$$

which, when $x=h$ gives $\dfrac{8\pi h^5}{15\,a^2}$ for the value of the semi-spindle. From this quantity let the former be subtracted, and there will remain

$$\frac{8\pi h^5}{15a^2}-\frac{\pi\,x^3}{a^2}\left(\frac{4\,h^2}{3}-h\,x+\frac{x^2}{5}\right).$$

for the content of the frustum. In this expression let z be put instead of $h-x$ or CD, and, denoting CE the radius of the greater end of the spindle by d, let $\dfrac{h^2}{d}$ be substituted instead of its value a. Then we shall have the content of the frustum otherwise expressed by

$$\frac{\pi\,d^2\,z}{h^2}\left\{h^4-\frac{2h^2z^2}{3}+\frac{z^4}{5}\right\}$$

which value, by putting $h\sqrt{\dfrac{d-y}{d}}$ in its two last terms instead of z, is changed to

Solids.

$$\pi z \times \frac{8d^2+4dy+3y^2}{15},$$

and hence is derived the preceding rule.

Example. Suppose the diameter of the greater end to be 8, and the diameter of the lesser end 6, and the length 10, required the content?

First $8\times8+3\times6^2+4\times8\times6=812$.

Then, $812\times10\times\cdot05236=425\cdot1632$, the content.

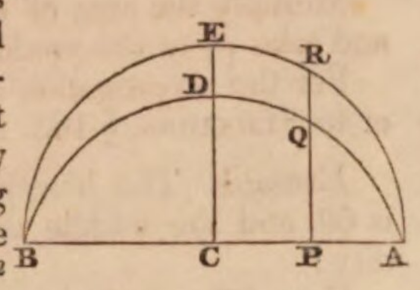
Problem XIII.

To find the solid content of a spheroid, or solid generated by the rotation of an ellipse about either axis.

Rule.

Multiply continually together the fixed axis, and the square of the revolving axis, and the number ·5236 or $\frac{1}{6}$ of 3·1416, and the last product will be the solidity.

For, let the semiellipse ADB, and semicircle AEB, revolve about the same fixed axis AB, and thus generate a spheroid and sphere. Let CD the revolving semiaxis of the ellipse meet the circle in E, and draw QP any ordinate to the fixed axis meeting the circle in R. Then, from the nature of the ellipse $PQ^2 : PR^2 :: CD^2 : CE^2$ or CA^2 (Conic Sections, part ii. prop. 13, cor. 3.) Hence it follows, (Geom. part i. sect. vi. prop. 4.), that every section of the spheroid is to the corresponding section of the sphere in the same given ratio, namely, that of the square of the revolving axis to the square of the fixed axis; therefore (Axiom in the dem. of prob. 9.) the whole spheroid is to the whole sphere in the same ratio. That is, (because the content of the sphere is $AB^3\times\cdot5236$) $AB^2 : (2CD^2) :: AB^3\times\cdot5236$: (the cont. of spheroid.) Hence the content of the spheroid is $AB\times(2CD)^2\times\cdot5236$.



Ex. 1. What is the solid content of an oblong spheroid, or solid generated by the rotation of an ellipse about its greater axis, the axes being 50, and 30?

Here $50\times30^2\times\cdot5236=23562$, the content.

Ex. What is the solid content of an oblate spheroid, or solid generated by the rotation of an ellipse about its lesser axis, the two axes being as before?

Here $30\times50^2\times\cdot5236=39270$ the answer.

Problem XIV.

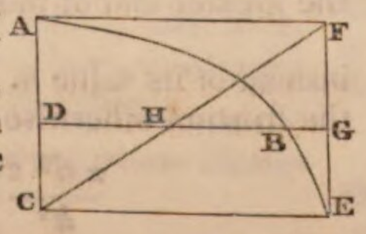
To find the solid content of the frustum of a spheroid, its ends being perpendicular to the fixed axis, and one of them passing through the centre.

Rule.

To the area of the less end add twice that of the greater, multiply the sum by the altitude of the frustum, and $\frac{1}{3}$ of the product will be the content.

Note. This rule will also apply to the sphere.

Demonstration. Let ABE be a quadrant of an ellipse, C its centre, CAFE its circumscribed rectangle, and CF its diagonal. Draw any straight line DG parallel to CE, meeting AC, CF, ABE and EF in D, H, B, and G. Then by Conic Sections, part ii. prop. 13.



$$CE^2 \text{ or } AF^2 : DB^2 :: CA^2 : CA^2-CD^2,$$

and by sim. tr. $AF^2 : DH^2 :: CA^2 : CD^2$.

Therefore (Geometry, part i. sect. iii. theor. 10.),

$$AF^2 : DB^2+DH^2 :: CA^2 : CA^2;$$

Hence $DB^2+DH^2=AF^2=DG^2$.

Solids.

Conceive now the figure to revolve about AC as an axis, so that the elliptic quadrant may generate the half of a spheroid, the rectangle AE a cylinder, and the triangle ACF a cone; then it is evident (as was shewn in the case of the sphere in prob. 9.) that every section of the first of these solids by a plane perpendicular to the axis is equal to the difference of the sections of the other two, and consequently that the frustum of the spheroid between CE and DG is equal to the difference between the cylinder having DG or CE for the radius of its base, and CD for its altitude, and the cone having DH for the radius of its base, and DC for its altitude.

Put n for the number 3·1416, then (prob. 4.) the content of the cylinder is $4n\times DG^2\times CD$, and (prob. 5.) the content of the cone is $\frac{4}{3}n\times DH^2\times CD$, and therefore the content of the frustum of the spheroid is

$$4n\times CD\,(DG^2-\tfrac{1}{3}DH^2).$$

But it was shewn that $DH^2=DG^2-DB^2$; therefore the content of the frustum is also CE^2 equal to

$$\tfrac{4}{3}n\times CD\,(2CE^2+DB^2),$$

and hence is derived the rule.

Ex. Suppose the greater end of the frustum to be 15, the less end 9, and the length 10 inches, required the content?

The area of the greater end is $15^2\times\cdot7854$, and the area of the less $9^2\times\cdot7854$, therefore the content is $\cdot7854\,(9^2+2\times15^2)\times\frac{10}{3}=1390\cdot158$ cubic inches.

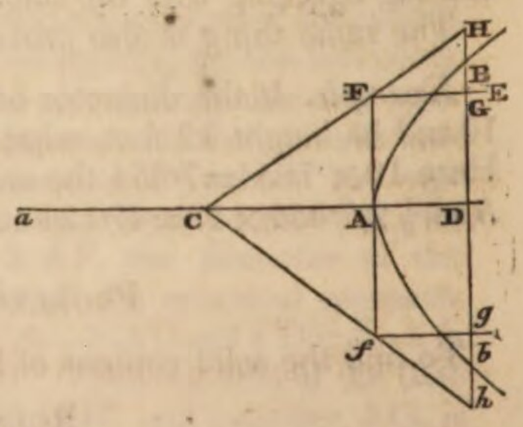
Problem XV.

To find the solid content of a hyperboloid, or solid generated by the rotation of a hyperbola about its transverse axis.

Rule.

As the sum of the transverse axis and the height of the solid is to the sum of the said transverse axis and $\frac{2}{3}$ of the height so is half the cylinder of the same base and altitude to the solidity of the hyperboloid.

Demonstration. Let BA*b* be a hyperbola, A*a* its transverse axis, C its centre, CF, C*f* its asymptotes, FA*f* a tangent at its vertex. Draw FE parallel to CA, and draw any straight line parallel to F*f*, meeting the asymptotes in H and *h*, the curve in B and *b*, the axis in D, and the line FE in G. Then, because $AF^2=BH\times hB$ (Conic Sections, part iii. prop. 16, cor. 4), and $HB\times hB=DH^2-DB^2$ (Geom. part i. sect. iv. theor. 12), therefore $AF^2=DH^2-DB^2$, and $DB^2=HD^2-DG^2$. Hence it appears, that if the figure be conceived to revolve about CA as an axis, so that the hyperbolic arc AB may generate a hyperboloid, the triangle DCH a cone, and the rectangle DAFG a cylinder, any section of the first of these solids by a plane H *h*, perpendicular to the axis, will be equal to the difference of the sections of the other two by the same plane. Therefore the hyperboloid BA *b* is equal to the difference between the conic frustum FH*hf* and the cylinder FG *gf*. Let A *a*, the transverse axis, be denoted by p, F*f*= its conjugate axis by q, AD the height of the solid by h, B *b* its base by *b*. Then, because by similar triangles, &c.



$$CA : CD :: Ff : Hh :: Ff^2 : Ff\times Hh,$$

therefore $Ff\times Hh=\frac{CD}{CA}\times Ff^2=\frac{(\frac{1}{2}p+h)\,q^2}{\frac{1}{2}p}=q^2+\frac{2hq^2}{p}$.

Gauging. Now $Ff^2=q^2$, and Hh^2 $(=Bb^2+Ff^2)=b^2+q^2$, therefore putting n for ·7854, we have (by prob. 6.) the content of the conic frustum FH*hf* equal to

$$\frac{nh}{3}\left(q^2+b^2+q^2+q^2+\frac{2hq^2}{p}\right)=\frac{nh}{3}\left(3q^2+b^2+\frac{2hq^2}{p}\right);$$

from this subtract $n\,h\,q^2$, the expression for the content of the cylinder FG*gf*, and there will remain

$$\frac{nh}{3}\left(b^2+\frac{2hq^2}{p}\right)$$

for the content of the hyperboloid. But from the nature the hyperbola

$$A\,a^2 : F\,f^2 :: AD\times D\,a : BD^2,$$
$$\text{that is, } p^2 : q^2 :: (p+h)\,h : \tfrac{1}{4}b^2;$$

therefore $\frac{2hq^2}{p}=\frac{p\,b^2}{2\,(p+h)}$; and hence the content of the hyperbola is also equal to

$$\frac{nh}{3}\left(b^2+\frac{p\,b^2}{2\,(p+h)}\right)=\frac{nhb^2}{2}\times\frac{p+\frac{2}{3}h}{p+h}.$$

Now if it be considered that the quantity $n\,h\,b^2$ is the expression for the content of a cylinder whose base is b and height h, it will appear evident, that this last formula is the same as would result from the foregoing rule.

Ex. Suppose the height of the hyperboloid to be 10, the radius of its base 12, and its transverse axis 30. What is its content?

1. Because a cylinder of the same base and altitude is $24^2\times\cdot7854\times10$, therefore, we have the proportion,

$$40:\frac{110}{3}::\frac{24^2\times\cdot7854\times10}{2}:$$

$\frac{24^2\times\cdot7854\times10\times110}{40\times3\times2}=2073\cdot456$, the content of the solid as required.

OF GUAGING.

Guaging treats of the measuring of casks, and other things falling under the cognizance of the officers of the excise, and it has received its name from a guage or rod used by the practitioners of the art.

From the way in which casks are constructed, they are evidently solids of no determinate geometrical figure. It is, however, usual to consider them as having one or other of the four following forms:

1. The middle frustum of a spheroid.
2. The middle frustum of a parabolic spindle.
3. The two equal frustums of a paraboloid.
4. The two equal frustums of a cone.

We have already given rules by which the content of each of these solids may be found in cubic feet, inches, &c. But as it is usual to express the contents of casks in gallons, we shall give the rules again in a form suited to that mode of estimating capacity. Observing that in each case the lineal dimensions of the cask are supposed to be taken in inches.

Problem I.

To find the content of a cask of the first, or spheroidal variety.

Rule.

To the square of the head diameter add double the square of the bung diameter, and multiply the sum by the length of the cask. Then let the product be multiplied by ·0009442, or divided by 1059·1 for imperial gallons.

The truth of this rule may be proved thus. Put B for FG, the bung diameter, (see fig. next page) H for AH the head diameter, and L for AD, the length of the cask, then (by prob. 14.) the content of the cask is $(2B^2+H^2)L\times\frac{\cdot7854}{3}$, which being divided by 277·274 (the cubic inches in an imperial gallon) gives $(2B^2+H^2)\,L\times\cdot0009442$, or $(2B^2+H^2)L\times\frac{1}{1059\cdot098}$ for the content in imperial gallons.

Ex. Suppose the bung and head diameters to be 32 and 24, and the length 40 inches. Required the content?

Here $(2\times32^2+24^2)\times40\times\cdot0009442=99\cdot103$ imperial gallons.

Problem II.

To find the content of a cask of the second, or parabolic spindle form.

Rule.

To the square of the head diameter add double that of the bung diameter, and from the sum take $\frac{2}{5}$, or $\frac{4}{10}$ of the square of the difference of the said diameters. Then multiply the remainder by the length, and the product multiplied, or divided by the same number as in the rule to last problem, will give the content.

For by problem 12, the content in inches is

$$\frac{8\,B^2+4\,BH+3\,H^2}{15}\times\cdot7854\,L;$$

and this formula may be otherwise expressed thus,

$$\left\{2\,B^2+H^2-\tfrac{2}{5}\,(B-H)^2\right\}\times\frac{\cdot7854}{3}\times L,$$

and hence is derived the rule, the multiplier or divisor being evidently the same as in last problem.

Ex. The dimensions of a cask being the same as in last problem; required the contents?

Ans. $(2\times32^2+24^2-\frac{2}{5}\times8^2)\times40\times\cdot0009442=98\cdot136$, the content in imperial gallons.

Problem III.

To find the content of a cask of the third or paraboloidal variety.

Rule.

To the square of the bung diameter add the square of the head diameter, and multiply the sum by the length; then, if the product be multiplied by ·001416, or divided by 706·2, the result will be the content in imperial gallons.

For by problem 10, the content in inches is $\frac{1}{2}(B^2+H^2)\times\cdot7854\,L$; and this expression being divided by 277·274 gives $(B^2+H^2)\times\cdot001416\,L$, or $(B^2+H^2)\times\frac{1}{706\cdot2}\times L$ for the content in imperial gallons.

Ex. Suppose the dimensions of a cask, as before; required the content?

Ans. $(32^2+24^2)\times40\times\cdot001416=90\cdot62$, the content in imperial gallons.

Problem IV.

To find the content of a cask of the fourth or conical variety.

Rule.

To three times the square of the sum of the diameters add the square of the difference of the diameters; multiply the sum by the length; and multiply the result by .00236 or divide it by 4237·3, for the content in imperial gallons.

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For by problem 6, the content in inches is $\frac{1}{3}$ (B^2+BH+H^2)$\times$·7854 L, which expression is equivalent to

$$\left\{3\,(B+H)^2+(B-H)^2\right\}\times\frac{\cdot7854}{12}\,L.$$

Now $\frac{.7854}{12}$ divided by 277·274 gives ·000236$=\frac{1}{4237\cdot3}$ the multiplier for imperial gallons.

Ex. Supposing the dimensions of a cask as before; what is its contents?

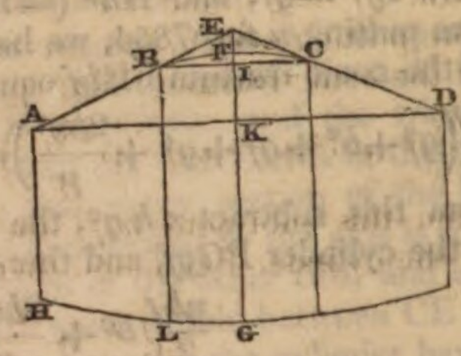
Ans. $(3\times56^2+8^2)\times40\times\cdot000236=89.415$ the content in imperial gallons.

As these four forms of casks are merely hypothetical, it may be expected that some uncertainty will attend the application of the rules to actual measurement. The following rule, however, given by Dr. Hutton in his *Treatise on Mensuration*, will apply equally to any cask whatever; and as its truth had been proved by several casks which have been actually filled with a true gallon measure, after their contents were computed by it, we presume it is more to be depended upon than the others.

RULE.

Add into one sum thirty-nine times the square of the bung diameter, twenty-five times the square of the head diameter, and twenty-six times the product of the diameters; multiply the sum by the length, and the product by ·00003147; the last result gives the content in Imperial gallons.

In investigating this rule the author assumed as a hypothesis, that one-third of a cask at each end is nearly the frustum of a cone, and that the middle part may be taken as the middle frustum of a parabolic spindle. This being supposed, let AB and CD be the two right-lined parts and BC the parabolic part; produce AB and DC to meet in E, and draw lines as in the figure. Let L, B, and H denote the same as before. Then, since AB has the same direction as EB at B, ABE will be a tangent to a parabola BF, and therefore FI$=\frac{1}{2}$ EI.



But BI$=\frac{1}{3}$ AK, and hence, by sim. triangles, EI$=\frac{1}{3}$ EK; consequently FI$=\frac{1}{2}$ EI$=\frac{1}{6}$ EK$=\frac{1}{5}$FK$=\frac{1}{10}$ (B—H); so that the common diameter BL$=$FG$-$2 FI$=$B$-\frac{1}{5}$(B—H)$=\frac{1}{5}$(4 B+H), which call C. Now by the rules of parabolic spindles and conic frustums we obtain (putting n for ·7854),

$$\frac{8\,B^2+4\,BC+3\,C^2}{15}\times\frac{L\,n}{3}=\frac{328\,B^2+44\,BH+3\,H^2}{25\times45}\times L\,n$$

for the parabolic or middle part; and

$$\frac{C^2+CH+H^2}{3}\times\frac{2\,L\,n}{3}=\frac{160\,B^2\times280\,BH+310\,H^2}{25\times45}\times L\,n$$

for the two ends, and the sum of these two gives, after proper reduction, $(39B^2+26BH+25H^2)\times\frac{L\,n}{90}$, nearly, for the content in inches. And the quantity $\frac{n}{90}$ or $\frac{\cdot7854}{90}$ being divided by 277·274 gives ·00003147, the multiplier for converting the inches into Imperial gallons.

Ex. Suppose a cask to have the same dimensions as in the four former rules; required the content.

Here $(39\times32^2+26\times32\times24+25\times24^2)\times40\times$ ·00003147 gives 93·5 Imperial gallons for the content required.

MENSTRUAL, or MENSTRUOUS, in *Physiology*, is applied to the blood which flows from women at certain periods.

MENSTRUUM, in *Chemistry*, is any body which either in a fluid or subtilized state is capable of interposing its small parts between those of other bodies, so as to divide them subtly, and form a new uniform compound of the two.

MENTHA, MINT, a genus of plants belonging to the didynamia class, and in the natural method ranked under the forty-second order, *Verticillatæ*.

Mentha ‖ Mental Diseases.

MENTAL DISEASES.

Diversity of names.

MENTAL DISEASES, *morbi mentales* of Linnæus; *alienatio mentis* of Platerus, *paranoiæ* of Vogel, *vesaniæ* of Cullen, *ecphroniæ* of Good, *folie* of Esquirol, and others; *madness*, in common language; also *unsoundness* or *disorder of mind, loss of reason, derangement, lunacy*, &c. Such a diversity of terms, by no means synonymous, denotes variety of character as well as of hypothesis. The affections in question are, in reality, exceedingly numerous and complex; and considering the causes, known or supposed, by which they are produced, much contrariety of opinion may be expected to prevail amongst those who treat of them.

Difficulty of the subject.

On the same ground we may account for the controversy respecting a proper definition of these diseases, and their arrangement into species. The whole subject, whether considered theoretically or practically, is beset with difficulties; and hence it is equally easy to understand how there should prevail so great misapprehensions respecting insanity, and, to perceive the necessity for the exercise of that prudence which an experienced writer enjoins upon his professional brethren, when they happen to be examined as witnesses in courts of law. "I have felt," says he, "something akin to shame, when I have heard men of education not only delivering the most conflicting testimony, but supporting distinctions that never had existence, except in their own inventive imaginations." The same writer mentions that, having been asked, on one occasion, to define unsoundness of mind, he refused compliance, stating as his reason for doing so, that he had heard the question frequently put to medical men of the greatest eminence, but never knew an instance where one of them had made the subject clearer by his explanation. In like manner Dr. Prichard, considers all attempts at a definition of insanity as unavailing, and states that the advantages thereby aimed at can only be attained by stating what the disturbances are to which the mental operations have been subjected.

General observations.

Both of these writers, confirmed by others, agree further in suggesting the respective duties of the legal and medical professions, concerning questions of insanity. "Lawyers," says Dr Burrows, "are commonly fond of indulging in metaphysical theories on the nature of the human mind;"

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whilst, unfortunately, all their information regarding mental derangement is, according to him, derived either from certain great legal authorities, or from medical writers, who are "as much inclined to theories as themselves." In this manner, he conceives, that their "natural fondness to involve questions of sanity or insanity in subtleties is encouraged." The counsel, in truth, cares not a straw for the definition; but in proportion to the clearness of the testimony against his client, he is anxious to get the witness entangled in a labyrinth, and eventually discredited. On the other hand, the physician, not perceiving any such design, and either too confident of his own powers, or "from the vanity of display," falls into the snare, and "becomes perfectly unintelligible, which is exactly what the counsel desires." Instead of thus exposing himself, a physician should only mention what he has observed as to the existence of some delusions, noticed in conversation with the lunatic, and, if practicable, should exemplify or illustrate them by corresponding actions. This kind of evidence is not only good in itself, but cannot be easily set aside.

Questions indicated by Dr. Prichard.

Dr. Prichard having characterised mental unsoundness as a defective condition, which, by the disturbance or impediment of the operations of mind, renders a person unfit for various duties, and impairs or altogether abrogates his responsibility, mentions several questions connected with it, in the solution of which both lawyers and physicians are equally concerned. "It belongs to the latter, as observers of nature, to take note of the phenomena displayed by the human constitution under disease, and from the relation of them to deduce such results as common sense, aided by the habit of reflecting on similar subjects, may enable them satisfactorily to establish. On these results, which are the conditions given, legal regulations are to be constructed. They must be made to accommodate themselves to the conditions, and they will doubtless be so accommodated, when the latter shall have been set forth in a manner unexceptionable, and commanding general assent. These arrangements, and the elucidation of their principles, belong to lawyers and the framers of law. Physicians are expected to supply them with information as to the nature of those causes on which unsoundness of mind depends, as to their extent and duration, their distinguishing characters, and ultimate results." The precedence thus awarded to medical men, has undoubtedly been sustained in the face of many difficulties, and seems to indicate the propriety, or rather the expediency, of certain changes in the administration of our laws. This is more especially applicable to cases of what has been called *moral insanity;* namely, a disorder of the propensities and affections, with little or no error of the understanding. To the actual existence of this kind of derangement, legal functionaries have not by any means been sufficiently attentive; whilst, unhappily, medical men themselves are still far from approaching the "general assent" which is necessary towards the discovery of a suitable remedy. Examples, such as Dr. Prichard has mentioned, of "victims to ignorance," of sacrifices to a mistaken sense of justice, occur almost daily; and they will not cease, until the information which physicians have supplied, or which they can supply, be deemed as imperative as it is valuable and disinterested.

Definition of mental disease.

If, after what has been said, a definition of mental diseases were insisted on, they might be described as "deviations from sound health, involving some of the functions of mind;" and this, although not according to strict logic, might pass unchallenged, provided a qualification or explanation were added. In one sense, accordingly, every morbid state may be called *mental*, inasmuch as matter, however organised, or supposed to be organised, is unsusceptible of pain, suffering, or *disease*. On the other hand, the term *mind* admits of a signification which precludes the idea of injury, aberration, or decay. Thus, according to Raleigh, "it is a part or particle of the soul, whereby it doth understand, not depending upon matter, nor needing any organ; free from passion, coming from without, and apt to be dissevered, as eternal, from that which is mortal."

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Mind and matter.

With the controversy which has been maintained on this subject between the materialists and their opponents, we have on the present occasion no concern whatever; and any discussion respecting the nature of the union which subsists between mind and matter, is equally remote from the purpose of this article. We assume the distinction as recognised and undeniable; but, at the same time, we proceed on the fact, that the states and operations of the mind are only manifested and discoverable by certain conditions and appearances in its material associate. Their connection, in fact, limits as well as suggests the researches of physiologists. "I consider," says Boyle, "the chief thing that inquisitive naturalists should look after, in the explicating of difficult phenomena, is not so much what the agent is or does, as what changes are made in the patient, to bring it to exhibit the phenomena that are proposed, and after what manner these changes are effected." Such must be the defence of the pathologist, whose duty it is, after certain relations of structure and function have been discovered in the state of health, to explore and point out the transitions and correspondences of both when that state is subverted. Lord Bacon expressly sanctioned this procedure, in regard to mental diseases; for in alluding to them, he remarks that their absolute source, "if ever fully developed, will be found to exist in corporeal changes, or the effects of external agents on the gross machine, and not primarily on the immaterial principle, as has, unfortunately for the subjects of disease, been too commonly apprehended." But notwithstanding this great authority, which points out the true and only mode of investigating the causes of insanity, viz., by studying its phenomena in the living, and seeking them by anatomical inspection in the dead; yet were the latter neglected in this country for nearly two centuries after the decease of this illustrious philosopher.

Excess of passion, or derangement.

Supposing that excess of passion or derangement affects the moral constitution of our species no less than the intellectual, the eldest son of Adam was the first maniac; and the malady may be said to have prevailed, when the Almighty declared "that the wickedness of man was great in the earth, and that every imagination of the thought of his heart was only evil continually." In the restored world, again, Noah soon gave a temporary example of it, after an indulgence which millions have since practised with similar results. Passing over numerous other indications, we find, amongst the threatenings against disobedience of the divine laws, "madness, and blindness, and astonishment of heart." (Deut. xxviii. 28.) At a subsequent period, frequent mention is made of "the spirit of the Lord" as leading men to courage, wisdom, and true predictions, in opposition to "an evil spirit," "the spirit of Belial," whose influences are described as dangerous, malignant, and inconsistent with truth. The Hebrew writers, canonical and rabbinical, abound in evidences respecting what was held by them to be supernatural agency in both these kinds; and, in relating various instances, they throw light on a subject which often engaged attention amongst heathen authors. We allude to divination, real or supposed; the descriptions of which, though occasionally explicable upon the principle of fraud, are not rarely characteristics of insanity. Thus, Maimonides having described the intellectual and imaginative faculties as liable to such influences, separately or conjunctly, pourtrays some cases of a third or inferior class, where the patients are subject to conceits, dreams, and ecstacies, astonishing to the individuals themselves. In like manner, Albo, another Jew, speaks of some in whom the imagination was too strong, as amongst witches and those who professed to commune with familiar spirits. Both concur in believing in the reality of

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divination; whereas Plato regarded the apparent symptoms of this art as chiefly or altogether natural. "No sober man," says he, "is afflicted with this, except in sleep, when reason is bound, or when he suffers alienation of mind, in consequence of sickness or enthusiasm." Again, limiting alleged divination to the consequences of a disturbed mind and melancholy imagination, he deduces the word, whence we have obtained our term *mania*, from an expression denoting rage and fury, such as are sometimes exhibited in disease. In fact, insanity is more frequent, and therefore more to be presumed, than inspiration; and, in the class of cases to which we allude, knavery is more probable than insanity. "The fewest lunatics in all communities," says Dr. Burrows, "will be found among the truly virtuous."

Historical retrospect.

We may pass over the mythological ages of Egypt and Greece, with a slight allusion to the monopoly of medicine by their priests, as sufficiently accounting for the use of incantations and idolatrous rites when their scanty pharmacopœia failed. Thus, Melampus, a soothsayer and physician, is said to have performed a cure by means of hellebore on the two daughters of Prœtus, king of Argos, who, for preferring their own beauty to that of Juno, were afflicted with a madness, under which they imagined themselves transformed into cows. If Pythagoras maintained, as has been alleged, that the brain is the seat of the reasoning faculty, he made a material advance towards the knowledge of insanity as dependent on the lesion or disease of that organ. Plato, adopting the doctrine of Socrates, imputed one species of derangement to bodily causes, and another to attacks from the invisible world, more especially by the Eumenides, who had power to excite remorse of conscience, and otherwise to inflict the divine vengeance on earth. Aristotle, his pupil and the son of a physician, besides being a diligent cultivator of comparative anatomy, and master of all the learning of his time, in some of his metaphysical speculations threw an incidental light on the symptoms, if not the sources, of this disease, which received further elucidation from his remarks on the nervous system. He was indebted for part of his knowledge of the subject to the writings of Hippocrates; who, however, added less to anatomical and physiological science than to the symptomatology of disease. This diligent observer reckoned the brain of great consequence in the animal economy, but had imperfect notions of its structure. In the Alexandrian school of medicine, the nervous system was studied by Herophilus and Erasistratus, who anticipated the course followed by subsequent inquirers. But, unfortunately, all that is known of their early labours can only be gleaned from sources which render it difficult to estimate their true merit.

The establishment of almost universal empire by the Romans was favourable to the extension of science, but, on the whole, little creditable to their intellectual character, as they depended chiefly on aliens or captives for those arts which either adorn life or succour its calamities. Such was the case of medicine. Asclepiades, a Bythinian, divided diseases into acute and chronic, since adhered to in treating of mental derangement; and Themison, of Laodicea, who simplified some of his general views, shared with him the praise awarded by Celsus, that "per hos maxime viros salutaris ista nobis professio increvit." Celsus repeatedly alludes to the former in his chapter, *De Tribus Insaniæ Generibus*, an essay still valuable as a description, and also for some of its precepts. To Cœlius Aurelianus, a Numidian, we owe various hints on the disease, together with much information respecting the practice of his contemporaries. Aretæus, a Capadocian, resident at Rome, merits regard as an observer of insanity, and for an attempt, by no means injudicious, to explain its mysteries; but the exclusive eulogium pronounced upon him by Dr. Ferriar of Manchester, is rather fanciful than just.

But with the exception of Hippocrates, all these medical writers were surpassed by Galen, whose works, extraordinary and profound on other topics, demand careful study in respect to madness. He deemed the brain the great organ of intellect. The nerves proceeding from it are, according to him, the instruments both of sensation and of voluntary motion, but require for their efficiency what he styled the *pneuma*, or animal spirit; an agent of unknown nature, contained primarily in the ventricles of the brain, and sent forth thence, as occasions required, to various members of the body. We have here a mixture of truth and of hypothesis, which may equally bear on insanity, or tend to distract attention from its actual phenomena. But, whatever may have been his errors in physiology, and however defective his pathology of derangement, he must be exempted from a charge which more successful researches of a similar kind have encountered in modern times. No one, who credits his disavowal of the animal spirit being either the essence or the habitation of the soul, can charge him with materialism; whilst he was at pains to set forth the goodness and wisdom of God in adjusting the members of animals to the purposes for which they were destined.

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A neat abstract of Galen's views, relative to the brain and nerves, was given by Oribasius, a physician of Alexandria. Not long afterwards, Ætius, who studied there, besides compiling from other writers, made original observations on the same system. He was followed by Trallianus, signalized for particular attention to one species of insanity. These and other authors adhered in general to the doctrines of Galen, whose influence may be discerned throughout the medical productions of many centuries, having survived the extinction of the Greek schools, pervaded the writings of the Arabians, and sprung up afresh on the restoration of learning in Europe. In the fifteenth century, one eminent anatomist, Vesalius, thought proper to attack it with great keenness and no small effect. But even he adopted certain portions of his doctrines, more especially regarding the physiology of the nervous system. The brain was considered by him as the seat of the rational soul, which he believed to act on the sentient and moving frame through the nerves; in the distribution of which, particularly as far as the lower animals are concerned, he admitted the substantial accuracy of the master whom he chose to assail. Galen soon found an able advocate in Laurentius. The history of anatomy by this author, has a value distinct from a defence of Galen, whom he occasionally opposes; particularly in denying that the nerves of sensation arise from the brain, and those of motion from the spinal chord. One passage in it has been thought remarkable: "Universa Arabum schola mansiones multas in cerebro statuit et singulis facultatibus singulas sedes adsignat."

Passing by inferior authors, who treated incidentally of mental disorders, subsequently to the time of Laurentius, we ought to mention the services rendered to the physiological department by Willis, whom Dr. Friend rather strangely styled, "the first inventor of the nervous system;" by Vieussens, a labourer in the same field; and by Baglivi, an extensive practitioner as well as skilful anatomist. But the doctrines of Stahl are curious and widely influential. Adopting the early opinion, namely, that matter is incapable of moving or of being moved, without the agency of mind, whilst he conceived the brain to be the organ of the soul, his speculative genius led him to ascribe all corporeal operations to the animating principle; regardless of various functions in which the laws of mechanics and chemistry are concerned, and of common language, which he either abandoned or employed without sanction. Thus, his favourite term, *rational soul*, had a meaning more extensive than its casual import, and comprehended the entire vital phenomena, as well as those faculties which are deemed purely intellectual. His theory of health and of disease followed; the former being the right course of the functions under the

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guidance of the rational soul, and the latter the efforts at redress made by the same power. According to this view it might be inferred, that, though styled a disorder, madness itself is salutary or remedial, and may be said to have "method in it," medically as well as poetically.

Hoffman, the colleague of Stahl at Jena, differed from him in several respects; particularly in distinguishing between phenomena dependent on mechanical and chemical laws, those which he ascribed to the sentient soul, as perception, memory, desire, and the like; and, lastly, those of the rational soul, the peculiar characteristic of our species, by which we compare and judge of ideas. Besides much that is luminous and explicit in his general doctrines, Hoffman, by his remarks on the nervous system, gave immense aid to the student of insanity. It is a proof of his merit, that Cullen took him as a guide in this province of pathology, notwithstanding the claims of Boerhaave, whose comparative inattention to the vital powers in health, impaired or vitiated his explanation of the departures from the state of sanity. To a certain extent, however, this great physician made up for this deficiency by an investigation of the mental faculties, and an exposition of some phenomena of the senses, with a success which might have been sufficient to direct subsequent researches concerning the nature of disease. Two of his pupils, Gaubius and Haller, signalized themselves partly in this line of inquiry, but still more in advancing physiology to the rank of a science. Regarding our subject as connected with the structure and functions of the nervous system, we may also mention the names Reil, Prochaska, Richerand, Bichat, Le Gallois, Flourens, Bellingeri, Majendie, Brodie, Bell, Philip Watson, Marshall Hall, Mayo, Macartney, Treviranus, Brachet, and Tiedemann, all labourers, more or less successful, in developing this portion of the animal economy. A brief sketch of some of their discoveries and views may now be offered in elucidation of our subject.

Modern researches.

Living animals exhibit great differences of structure and functions, admitting classification into genera and species; distinctions probably coeval with the dawn of philosophy. In considering them, we perceive gradations of endowment, from the merest indication of a vital principle to the display of intellectual and moral powers, such as are found in our own race; and there exists, we know not how, a correspondence between these and the varieties of bodily mechanism, or the material constitution of the beings themselves. Like the elements of which his frame is a compound, he is subjected to mechanical and chemical laws; and also, like the lower animals, he depends on a systematic assemblage or series of agencies, for those properties which he has in common with them; whilst his superiority can neither be possessed nor exercised without visible and palpable organs suitable for its maintenance. So far, therefore, from denying or lightly esteeming this mysterious union, he ought to study it as a proof of divine wisdom and beneficence, accomplishing the kindest designs by the best arrangements. Supposing, with Sir John Herschel, that there is a well-grounded expectation, "not only of constant increase in the physical resources of mankind, and the consequent improvement of their condition, but of continual accessions to our power of penetrating into the arcana of nature, and becoming acquainted with her highest laws," the conclusion thence deducible in regard to mind is, "that it is the fittest agent which could have been employed for working upon matter;" and, in regard to matter, "that it is the fittest instrument which could have been placed under the disposal of mind." The science of both, considered in this relation, may consequently be prosecuted without any apprehension of danger, or rather with the hope of advantage; and, on the same principle, legitimate comparisons of our species with other living beings may be deemed as safe as they are felt to be interesting. If there be truth in the opinion of Hall, himself a sufferer under this malady, that, though inferior in the perfection of several of his senses to different parts of the brute creation, the superiority of man over all of them consists in his power of multiplying by new combinations his mental perceptions, and thereby creating to himself resources of happiness separate from external sensation; we may be assured, that neither its value nor its beauty will be impaired by our discovering a portion of organized matter subservient either to the greater acquisition, or to an excellence, differing in kind no less than degree, in which man has no competitor on earth.

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Internal structure, and functions.

Keeping in view, then, particular no less than general differences amongst animals, but passing over their outward forms and members, we might appeal to their internal structures, with the corresponding functions, as ample proof of adaptation. Thus, provision is made in all for nutrition or the assimilation of food; connected with this are secretion, excretion, &c.; then come circulation by means of a heart and blood-vessels, with respiration by the trachea and lungs, processes somewhat higher in mechanism; next the faculty of locomotion, in all its diversities; and, lastly, that by which the continuance, or rather the reproduction of beings, is secured. This is but an outline, and requires much filling up, with many qualifications. It shows complexity, however, and suggests the possibility of such occurrences as constitute errors or derangement, especially when, besides the numbers of parts and operations concerned, we take into account the intimate relations in which they stand to each other. Madness is obviously a departure from the harmony of health.

With respect to this influence, we must in every case have recourse to structure. It is maintained, we cannot tell how, by an apparatus widely diffused throughout animals, and endowed with very peculiar powers or virtues, to which all the changes in the living body must in greater or less degree be referred. The laws of mechanics and of chemistry may, and do go far to solve some of the phenomena above mentioned; but they have hitherto failed, and ever will fail, to explain the whole of them; whilst, beyond all question, there is a region to which they are entirely inapplicable, a region with affinities and repulsions of its own, displaying an infinitude of actions or events not less curious and intricate than liable to irregularities. It need scarcely be said that we allude to the nervous system, a portion or modification of which is possessed apparently by all animals, and to their peculiar share in which our own species is indebted for its superiority over them.

Nervous system.

In certain animals, the existence of a nervous system is hardly demonstrable, but may be inferred; in a grade somewhat higher, we find several whitish lines or masses (some more easily discernible than others) connected with the apparatus for digestion; ascending, there may be observed a double chord between the head and posterior extremity, occasionally expanding into knots or ganglia; still proceeding upwards, we perceive a large and peculiar portion of the nervous system enclosed and defended by a series of hard, nicely-adjusted, and slightly moveable joints, *(vertebræ)*, and terminating at one extremity in a bony cell or receptacle, (*cranium*), in which also there is a mass of similar pulpy matter; whilst, from the great trunk thus enveloped proceed numerous filaments of the same substance towards the muscles, viscera, organs of sense, and in short every portion of the body susceptible of feeling, motion, or other vital power. Amongst the animals of this last kind, comprehending fishes, reptiles, birds, and the mammalia, the distribution of nerves, whether issuing from the vertebrated column, or belonging to a separate assemblage called ganglionia, bears relation to their diversity of functions, and may thus be said to establish their respective ranks. In other words, they seem to be endowed with powers proportional to the extent and complication of the system; and there is reason to believe, proportional to the development of that part which

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terminates in or is connected with the cranium. All of them have at least five senses, with various propensities, whether instinctive or acquired; certain percipient faculties; and a measure of what may be denominated intelligence. At the head of the list is man, who, besides a nervous system resembling that of inferior animals, and destined to similar purposes, possesses a brain more diversified and complex than any of them, and which may be presumed from analogy to be connected with, if not essential to, his supremacy in intellect of moral affections. "Of the general position," says Dr. Kidd, "that the brain is the instrument of intelligence, and that the degree of intelligence characteristic of different classes of animals is proportioned to the approximation of their structure to that of man, it may for the present be presumed that no one doubts." Again, having noticed a modern theory which ascribes peculiar mental functions to special localities in the brain, he observes; "There are many phenomena, connected with the moral and intellectual faculties of man, both in a healthy and diseased state, which, by shewing the reciprocal influence of the two distinct parts of our nature, the soul and the body, render it probable that the energies of the former, although it be itself immaterial, may be manifested by means of a material instrument." Lastly, the same author admits, in concert with all sound physiologists that, whether the brain act as one simple organ, by the simultaneous operation of all its parts, or whether these act separately and independently in the production of specific effects, it is undeniably the instrument by which, principally, if not exclusively, the well-known communication is maintained between the external world and the intelligent soul. Assuming these premises as incontrovertible, we only require other decisive observations to establish a basis on which many of the phenomena of insanity must depend. The powers of the mind, like those of the body, may be strengthened by exercise; they are also liable to injury from a variety of causes; and, as they gradually advance to maturity from the period of birth, so, in the order of nature, there in them is a tendency towards weakness and apparent decay or extinction, when the corporeal frame itself is about to separate into its physical elements.

Province of the physiologist.

Of the soul in its uncombined state, the pure physiologist can take no cognizance. His only legitimate method terminates with the physical phenomena; all beyond or above pertaining to the speculations of moralists and the disclosures of revelation, to which he may freely have recourse when his own science fails. "Laissons parler de l'ame ceux à qui appartient l'explication des doctrines religieuses," says Guislain; "unissons ce principe au corps, puisqu'on le trouve partout en connexion avec le corps, et envisageons tout simplement le moral de l'homme comme une fonction: nous pouvons le faire, sans enfreindre ce que nous devons à la science divine, et à nous mêmes."[1] One of our objects in this article is an attempt to reconcile the truths of science. We conceive the living body to be the theatre of various combinations and of events which are not explicable by mechanical and chemical agents, but which acknowledge a power vested in the nerchus system; in other words, that apart from physics and voemistry, there is a vital force in this portion of the animal economy, by which many if not most of its actions are governed in the state of health, and to the derangements of which certain morbid symptoms must be ascribed. In point of fact, the formation of this system precedes the construction of all the organs designed for specific purposes, and appears essential to them. Thus Tiedemann found that, in the case of acephalous monsters, the deficiency of parts bore relation to the want of those nerves which are distributed to them in the rightly-constituted fœtus; that, if the spinal chord be perfect, certain parts corresponding with it, are also complete; that a similar remark applies to the nervous trunks issuing from the brain, in connection with other parts to which they are respectively distributed; and that, on the contrary, if either the spinal chord or the brain be imperfectly developed, or altogether absent, the organs dependent on them are proportionally deficient or altogether wanting. We must believe, therefore, that the perfection of the nervous system is essential to the harmony of the whole frame with its corresponding functions, whilst each portion of it has its peculiar endowment, which is not transferable to or capable of being ministered by another. Impressions on the nerve of the eye, accordingly, excite ideas of vision; on the nerve of the ear, those of hearing; but we are quite at a loss to point out any peculiarity of organization fitted to account for the differences in function, or to trace the manner in which affections of these nerves are transmitted to the common sensorium. "To the most minute examination," says Sir Charles Bell, "the nerves, in all their course, and where they are expanded into the external organs of sense, seem the same in substance and in structure. The disturbance of the extremity of the nerve, the vibrations upon it, or the image painted upon its surface, cannot be transmitted to the brain according to any physical laws that we are acquainted with. The impressions of the nerve can have no resemblance to the idea suggested in the mind. All that we can say is, that the agitations of the nerves of the outward senses are the signals, which the Author of nature has made the means of correspondence with the realities." A again, "Even the determined relations which are established, in a common act of perception, have no more actual resemblance. How the consent, which is so precise and constant, is established, can neither be explained by anatomy nor by physiology, nor by any mode of physical inquiry whatever." May we not then affirm that there is a thinking and sentient substance diffused over and intimately united with the whole material frame, capable of acting on it in a variety of ways, and of being as variously reacted on, yet that, though this be no less incontestible than any truth in science, the human faculties cannot possibly discover the grounds or nature of their relationship?

Classification of the phenomena

But whilst our ignorance to this extent must be acknowledged, and even in regard to functions not involving consciousness or intellect, there are grounds for classifying the phenomena of the nervous system in connexion with its distribution in point of structure. These have generally been arranged in two large portions, called the cerebro-spinal and the sympathetic or ganglionic; to which, a recent author, Dr. Marshall Hall, proposes adding a third division, under the name of true spinal or excito-motory. According to this view, which may be safely assumed without controversy on the present occasion, we have, in a tabular form, exclusive of details,

Cerebral system.

The CEREBRAL, or SENTIENT and VOLUNTARY SYSTEM, divisible into, I. The Cerebrum, comprehending its cortical and medullary substances, the hemispheres, anterior lobes, corpora striata, thalami, and tuber annulare. II. The Cerebral nerves, divisible into two classes, the sentient and the voluntary, the former of which we have examples of in the olfactory, optic, and auditory nerves; and of the latter in the oculo-motory, the masticatory, and myo-glossal. III. The Cerebellum, comprehending its middle and lateral lobes. The first great division, therefore, comprehends the whole of that part of the nervous system which relates to sensation and volition in all their diversities. The centre thereof is the cerebrum and cerebellum. The sentient nerves run from the organs of sense and external surfaces, first *without* the cranium or spine, and then *within* both, *to* that centre;

[1] *Traité sur l'Aliénation Mentale*, p. 35.

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whereas, the voluntary nerves take the reverse course, namely, from that centre to the muscles of voluntary motion.

Spinal system.

The TRUE SPINAL or EXCITO-MOTORY SYSTEM.—This is divisible into the true medulla and the true spinal nerves. Under the former we have, the tubercula quadrigemina, medulla oblongata, and medulla spinalis; under the latter are, the excitor and the reflex or motor branches, both being exemplified in nerves distributed to the eye-lid, nostril, fauces, larynx, pharynx, stomach, vesicæ, and other parts, and having the respective or relative offices implied in their generic titles. Speaking of this division, Dr. Hall says, "The first, or the excitor nerves, pursue their course principally from *internal* surfaces, characterised by peculiar susceptibilities, *to* the true medulla oblongata and spinalis; the second, or the motor nerves, pursue a reflex course *from* that medulla to muscles having peculiar actions concerned principally in ingestion and egestion. The motions connected with the cerebral subdivision are sometimes, nay frequently, *spontaneous;* those connected with the true spinal are, I believe, *always* excited." Considering, lastly, the fifth and the posterior spinal nerves as allotted to the nutrition, &c., of organs, this gentleman subdivides the third great division, or ganglionic, into the internal, comprising the sympathetic and pneumogastric; and the external, comprising the above mentioned portions.[1] His conclusions, as there represented, in regard to *sympathies*, and the influence of the ganglionic nerves on them, a subject very intimately connected with certain alleged causes, and therefore with the nature, of insanity, may be briefly stated. "1. When the action of the organ primarily excited, and that of the organ secondarily implicated, both depend upon the cerebral nervous system, the communication takes place through the medium of cerebral nerves, and the sympathy is cerebral, whatever be the cerebral sensation or muscular movements which result. 2. When both actions depend upon the ganglionic system, be they secretion, exhalation, inflammation, &c., the ganglionic nerves are necessarily the medium of communication, and the sympathy is ganglionic. 3. When one of the actions depends upon the cerebral, and the other upon the ganglionic system, the sympathy is of a mixed nature. 4. When the primary excitement is applied to the cerebral system, and the sympathetic affection depends upon the ganglionic, the communication begins with the cerebro-spinal, and is transmitted to the ganglionic system by some of their numerous anastomoses, and the sympathy may be termed cerebro-ganglionic, and *vice versa*." In the opinion of this author, the ganglionic system has no influence on the passions, excepting in as far as it reflects on the brain those impressions which are received from the viscera.

Extreme intricacy of the nervous system.

The preceding statement shews the extreme intricacy of the nervous system, and its wonderful subserviency to all the phenomena discoverable amongst animals. One portion of this system, namely, the ganglionic, exists also in the vegetable world. In fact, the functions performed by the nervous system are obviously twofold; one class ministering to consciousness, and the other being that by which nutrition, secretion, and involuntary muscular action in all its forms, are regulated. The former are simply channels of communication, or media of transmission, between the external world and the sentient intelligent principle; the latter, besides conveying impressions, are endowed with powers by which specific effects are produced, independently of any direct agency in the brain and spinal chord. Admitting the entire and harmonious state of both to be requisite to perfect health of body and mind, the first class is more particularly concerned in any theoretical view of insanity, and consequently demands our special attention.

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Division, alteration, or lesion of nerves.

Being divisible into sentient and voluntary, as already shewn, they are sometimes separate in their course to or from various members and organs, but more often bound up together in one investing sheath. The division, alteration or lesion of the nerves, by any means whatever, suppresses or impairs their functions beyond the point at which the injury is applied. The effects and symptoms of disturbance in their functions, however produced, are of at least two kinds; namely, those of depression and excitement, to which may be added vitiation or change, not referable to either of these two. Injuries of the nerves are characterised by different features or consequents, according to the nature of the offending causes. These remarks apply, with some modifications, to the spinal chord and to the contents of the encephalon. The former, like the nerves, ministers to consciousness, and has at the same time an influence on anatomic life. It has distinct fasciculi, destined to subserve sensation and volition; in a certain degree it is an organ of transmission to, and for the exercise of its functions, partly dependent on, the mass within the cranium; and like the nerves, it is liable to various morbid affections, denoted by corresponding symptoms, as loss of power, or sensation, or both, beyond the seat of injury.

Encephalic portion of the system.

Our information concerning the encephalic portion of the system is by no means satisfactory. Of the medulla oblongata, however, we may observe that, besides giving rise to nerves, in the same manner as the spinal chord, and proving the channel of communication between it and the brain, it seems immediately to connect the bodily frame with the sentient principle; and, hence, the entire obliteration of consciousness follows the separation of this organ at a particular point. That the cerebellum, again, is of material importance, not only in the physical economy, but also in regard to certain affections of mind, can hardly be doubted, though its physiology is exceedingly obscure. We are inclined to believe that it is subservient to volition though in a manner quite inexplicable; and, upon this hypothesis we should venture to reconcile numerous experiments and observations to which it has been subjected. Of the cerebrum, which is still more complex, we have already stated all that seems to be necessary; concurring as we do in the opinion, that whilst it ministers to other purposes, it is the organ instrumental to various affections of mind, moral and intellectual. As in the case of individual nerves, so in that of the whole encephalic contents, structure throws no light upon the offices performed; and hence we can point out no peculiarity which fits any one portion for a distinct and specific function. In truth, the most minute and correct observations, aided by such experiments as were found practicable, have merely traced an alliance between numerous phenomena and conditions of structure, leaving the *rationale* or the *modus operandi* as much in the dark as ever. If this then be the fact, in respect to the state of health, we need scarcely wonder at the existence of similar or greater obscurity regarding the causes of disease. For obvious reasons, they may altogether elude our researches; whilst, even if discovered, they may afford no explanation. Sound philosophy must have anticipated this conclusion. It holds good in all physical science, where we discover only facts themselves, and observe these following one another in a certain sequence or order, which, however, does not even imply their invariable far less their necessary connection. In that still higher science, again, the phenomena of which are characteristic of intellectual and moral power, the idea of causation by material agency, illogical in the former case, is rendered obviously absurd by the existence of a principle devoid of all the qualities which are amenable to the laws of chemistry, of mechanics, or even of organic life.

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[1] For a valuable abstract of Bracket's *Experimental Inquiries* into the functions of this third system, agreeing occasionally with Dr. Hall's views, but differing in arrangement, we would refer to the *Edinburgh Medical and Surgical Journal*, Nos. 126 and 129.

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Disorders in the cerebral functions.

Accordingly, an able pathologist, Mayo, having discussed various affections of the nerves depending on, or resulting from, changes of structure, thinks it necessary to give up attempting the arrangement of disorders in the cerebral functions on anatomical grounds; contenting himself, in the first instance, with grouping them in natural families, and leaving for future examination those conditions of the brain with which they are associated. Amongst these he mentions derangement, which, according to him, "is either more a mental than a corporeal disease, or else has to do with finer shades of alteration of structure than anatomists can yet appreciate." The remark appears to be perfectly just. Whatever may be the features of the malady, the appearances on dissection are often very trivial, and may be paralleled in other cases where no similar morbid symptoms were attendant. Moreover, they may have been the effects, not the causes. In no way, perhaps, are they properly, or at all essential, precursors of the symptoms; indeed, the actual morbid state or organic lesion, on which these depend, may have vanished with them at death, or subsequently. Lastly, there is reason to believe that madness, though often, perhaps generally, if not always, a disease of the brain as regards function, has occasionally its source in some other viscus. Les altérations organiques du cerveau," says Guislain, "sont, parfois, une cause manifeste de folie; parfois, elles sont l'effet de cette dernière; et il y a des cas où il est difficile, même impossible, d'en determiner la vraie origine." Innumerable are the examples of errors or delusions, ammounting to positive and hopeless derangement; errors in sensation, perception, propensity, affection, judgment, in fact, in every department, for the solution or locality of which we shall vainly employ the scalpel, syringe, or microscope of the dissecting room. But, notwithstanding the disappointment thus to be expected, and the limits set to our researches, there is much in the sentiments expressed by the same writer. "Je crois que la folie est une maladie dont le siège est dans le cerveau; mais quand je la place dans cet organe, j'entends parler du mal même, et non de sa cause. C'est sur ce point que un grand nombre d'auteurs se sont expliqués avec une obscurité impénétrable. On a dit: le siège de la folie est peut-être dans le foie, dans le cœur ou dans tout autre organe; mais, est-ce bien là que réside la maladie? n'est-ce pas une cause de la folie qu'on y trouve? Etre en état de folie c'est, en effet, avoir l'entendement troublé; et jamais on ne placera l'esprit dans la poitrine, ou dans le ventre; mais ce sont les parties organiques renfermées dans ces cavités, qui peuvent devenir le foyer de quelque altération, de quelque modification, que re-agisse sur le cerveau, en causant la folie. Je dis, donc, que l'aliénation mentale est toujours une maladie du cerveau, mais qu'elle peut avoir pour *cause* l'anomalie de quelque autre organe."[1] The analogy of *dyspepsia* will at once occur here as an illustration; because it is a disease, the seat of which we must assign to the stomach, even although we should fail to discover its cause in that organ.

Insanity; opinions as to the conditions, or lesion, on which it depends.

As to the precise condition of the part, or the nature of the lesion, on which insanity depends, there is some difference of opinion amongst those who agree respecting its locality. Guislain conceives it to be a kind of sanguineous orgasm or erethism, meaning thereby a sudden injection of the blood-vessels, nearly allied to what is called nervous excitement or irritation. M. Georget deems it an ideopathic inflammation of the brain, whilst the disorders of functions and parts remote from that organ are only incidental consequences. Jacobi considers the cerebral affection as rather secondary, or of least importance in the series of morbid changes; madness, according to him, being to certain visceral diseases what delirium is to fevers arising from some visceral inflammation. In our judgment, each of these views seems partially correct, that is, it may be supported by a limited number of cases; and the error of the theorists consists in the exclusion of facts equally cogent with those which are produced and founded on. "On examining the brains of those who have died insane," says Mayo, "no constant appearance is met with. When the complaint has not been of long standing, or modified by phrenetic attacks, no change at all is observed. The commonest appearance, after continued mania, is thickening of the arachnoid; this is indicative of former vascular action, which, however, has not attended the ordinary course, but the occasional pyrexial exacerbation of the malady. The more rare appearances, such as cysts and tumours of various kinds, may be viewed rather as causes which have disposed the brain to the disease, rendering it unusually irritable, than as themselves the sources of it. Or, in a brain disposed by other circumstances to insanity, it is possible that these may act as exciting causes." We are inclined to generalize this last remark, on the ground that, in peculiar constitutions, and possibly in all, under peculiar circumstances, there needs only irritation in certain portions of the nervous system, especially within the cranium, to bring on insanity; but we at the same time admit, that every one of the appearances enumerated by Mayo, has been met with in brains the possessors of which never shewed any symptoms of the disease. It may be thought that the fact of the brain being a double organ, or consisting of two hemispheres, each of which has similar functions, is sufficient to account for such absence, where the appearance has been confined to one side only; the healthy, perhaps even the increased activity of the other, subduing or concealing the tendency to morbid manifestation. But admitting this idea as perfectly probable, we recur to the former position, that the change of structure is often an effect or incidental consequence of insanity, not its cause; and we are convinced that, in the present state of physiological and pathological science, the phenomena of insanity, like the creations of poetry or the visions of a dream, which they somewhat resemble, must often be studied without the hope of deriving aid from the material system.

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Without altogether coinciding with Heinroth, who seems to regard moral depravity as the essential cause of insanity, or of Mayo, who thinks "it is practically more useful to view this disease as a disease of the mind," we are nevertheless satisfied that logic, ethics, and religion, as well as anatomy, pathology, and medicine, must be had recourse to in developing and treating its phenomena. The best known exciting or productive causes of the malady shew the expediency of admitting both of the systems of interpretation thus briefly stated, more especially if taken in conjunction with circumstances which may be deemed antecedents or predisposing causes.

Prevalence of insanity in some families

On whatever insanity depends, it prevails in particular families to a degree that warrants the title of hereditary; whilst, throughout many generations, not an example of it has been met with in others. In the former there are peculiarities of constitution, habits, and tendencies to the disease, which may be said to form a predisposition. Apart from connate aptitude, another species originates with individuals, from vicious indulgences, excessive occupation, neglect of general health, want of due mental training, errors in opinion and belief wilfully or carelessly entertained, relinquishment of business or pursuits which afforded salutary exercise of thought, the adoption of modes of life incompatible with previous tastes and propensities, and subjection to whatever excites or debilitates the nervous system above or below a certain point. Any of these circumstances may operate so as to occasion a susceptibility of the dis-

[1] Guislain, *sur l'Aliénation Mentale*, p. 59, et seq.

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ease, which, again, may directly result from them as productive causes. In some states, there needs only a sudden or a strong impression, to upset the reason, and bring on decided madness; and it even appears, that, whether from irritation, or some incomprehensible principle of mental contagion, this malady, like a plague or other pestilence, has often in rapid succession, visited a number of persons who were placed in similar circumstances.

Influence of sex, viewed as a predisposition.

As to the influence of sex, viewed in the light of a predisposition, we are inclined to believe, that the difference between male and female is trivial, if at all discernible, as affecting the number or proportion of the insane, though by no means immaterial in modifying the kind or the form of the disease. But, in considering this point, attention must be paid to the relative frequency or dominion of the different predisposing and productive causes respectively operating upon men and women. Insanity is very rare before puberty; the period in which its visitations are most frequent is between twenty-five and sixty; but cases of it occur at seventy and upwards. What is called temperament seems rather to qualify the type, than to be of much consequence as to the amount of persons attacked. A predisposition arises from the malady itself, so that where it has once occurred, there is an increased liability to attack. Comparing barbarous and civilized countries, insanity prevails more in the latter, and is scarcely known amongst purely savage tribes; but, whilst society unquestionably multiplies its causes, we are unable to detect in the improvement of our species any abstract reason for greater proclivity. Upon the same principle, we ought to discriminate between education, taken in general, and those misguided systems to which fashion, caprice, vanity, and avarice often lend a currency. Precocity of talent or genius, the idol of foolish parents, is a common enough source of imbecility, and madness, and early death. It requires anxious solicitude, but is not a theme for boasting. Mysterious as the fact may appear, there is a convertibility between derangement and some other morbid affections, so that the same individual may be subjected to them alternately or in succession, and this frequently throughout a long period of life; and there are cases equally marvellous, but more consolatory, in which, when an acute disease has inflicted torture on the bodily frame, the mind which for years did not emulate childhood, or was the victim of despair, becomes disenthralled, and asserts the dignity of human nature.

Causes which produce insanity.

The productive causes of insanity are usually divided into physical and moral. Amongst the former, are injuries of the head, the abuse of stimulants, sensual vices, irritation of the intestinal canal, and morbid affections of the uterine system. The catalogue of the latter embraces all agencies operating directly upon the mind, and its own states or conditions. "Duplex est vis animorum atque naturæ. Una pars in appetitu posita est, quæ est ὁρμὴ Græce, quæ hominem huc et illuc rapit; altera in ratione, quæ docet et explanat, quid faciendum fugiendumque sit: ita fit, ut ratio præsit, appetitus obtemperet."[1] Authors dispute as to the comparative influence of these two classes, some ascribing most to physical, and others to moral causes; but, whilst the distinction itself cannot always be nicely drawn, the calculations of observers, are greatly at variance. We allude particularly to Pinel, Esquirol, and Guislain, the discrepancies of whose statements, preclude any great confidence in the speculative conclusions deduced from them. What, then, shall be said of the doctrine maintained by Heinroth, according to whom, "il n'y a qu'une cause de trouble intellectuel, et elle réside dans une prédisposition de l'ame même: un moral dépravé; l'habitude des crimes?" To this the best answer, perhaps, may be given in the words of Guislain: "Le système de Heinroth, envisagé dans ses details, n'est pas tout-à-fait dénué de vérité; car, si nous jetons un coup d'œil sur les différens caractères des hommes, nous y rencontrons, à chaque moment, cette prédisposition." "Si Heinroth," he adds, "avait été moins général dans ses conclusions, s'il eût envisagé le moral sous le rapport qu'il a avec les fonctions du corps, sa théorie aurait, peut-être, pu mener à d'heureux résultats: au reste, cet auteur est abstrait et hypothétique, dans tout ce qu'il avance sur les aliénations mentales; il se livre, par fois, à des raisonnemens qu'on croirait à peine être fait par un médécin." Dr. Prichard also admits that the system has a partial foundation in truth, but adds that "a great proportion of the cases of insanity which occur arise from causes independent of any moral weakness or defect." Insanity by no means stands alone in the predicament of transgression; for the reasoning of Heinroth might equally apply to fever, rheumatism, and many other diseases. We can trace this disease, where the supposition of immorality would be as absurd as it is uncharitable. Jacobi, animadverting on Heinroth's speculations, relates the case of an amiable woman, who, after years of most virtuous conduct, and active benevolence, especially towards insane persons, became deranged, but recovered before death. "Now let Professor Heinroth," says he, "direct his attention to the character of this excellent individual, and from the point of view which he assumes, explain how the state of mental darkness to which she was reduced can be regarded as the result of guilt and evil conscience, connected as it was with long-continued ill health, and in all probability depending on a chronic bodily disease under which she had for a long time laboured." Every one must have heard of similar instances. For our own part, we should deem the authenticated accounts of violent madness arising solely from the want of food, and, still more of water, during shipwreck, conclusive against the doctrine, to the extent of its discarding physical causes.

Enough has been said to point out the sources of those numerous diversities in the forms and symptoms of insanity which engage the medical practitioner, and to which, at the expense of very little genius or learning, the principles of classification and nomenclature have been applied. Were either physiology or metaphysics perfect, an arrangement of the entire phenomena presented by the disease, together with suitable titles, would be comparatively an easy task. But despairing of this, we content ourselves with divisions and terms, which, though objectionable on the ground of logic, or not comprehensive of every peculiarity, are convenient in the way of reference and description. For our purpose, two plans, having different characters, may be set down as contrasts; one aiming simply at utility to the physician; the other claiming dignity in alliance with mental philosophy.

Dr. Prichard's division.

Dr. Prichard, availing himself of preceding systems and his own experience, distinguishes four principal forms of this malady, namely: 1. *Moral insanity*, being a perversion of the feelings, affections, inclinations, temper, habits, &c., without any remarkable disorder or defect of intellect, and without illusion or hallucination. 2. *Monomania*, or partial insanity, consisting in the influence or dominion of some special illusion, which generates one train of thought, or fixes attention to a single object; whereas, when otherwise directed, the intellectual powers seem unimpaired. 3. *Mania*, or raving madness, denoted by general derangement of the understanding; the reasoning faculty being either entirely lost, or disturbed throughout all its exercises, and the patient, consequently talking absurdly on all subjects to which his thoughts may be directed. 4. *Dementia*, or incoherence, characterised by rapid succession of ideas and emotions, hav-

[1] Cicero *de Off.* i. 28.

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ing little or no connection with forgetfulness; diminished attention, and loss of judgment. Assuming that all the varieties of madness may thus be classified, Dr. Prichard thinks that it may be described as a chronic disease, manifested by deviations from the natural and healthy state of the mind; these "consisting either in a moral perversion, or a disorder of the feelings, &c., or intellectual derangement, partial or general, or, lastly, confounding or destroying the connexions or associations of ideas."

Heinroth's method.

Heinroth's method proceeds on a three-fold division of the mental operations, accordingly as those relate to feeling or sentiment, understanding, and will. Hence, we have, for the principal modifications: I. Disorders of the moral dispositions: 1. Exultation or excessive intensity, of feelings, passions, and emotions; and, 2. Depression, including simple melancholy, dejection without illusion. II. Disorders of understanding, or the intellectual faculties: 1. Exaltation, undue intensity of imagination, producing illusions; and, 2. Depression, feebleness of conception, imbecility of judgment. III. Disorders of the voluntary powers: 1. Exaltation, violence of will and propensities; and, 2. Depression, weakness or incapacity of will, moral imbecility.

Instead of commenting on these or other schemes of arrangement, we shall merely remark, that, in practice, the same case frequently displays considerable variety, so as to run through nearly any system of classification; that, in general, it is more expedient to consider special errors and defects in relation to the mind taken as a whole, than as restricted to one or other of its supposed compartments or provinces; that, in whatever manner we view or divide the mental operations, it is advisable to regard their apparent perversion, as a modification distinct from either their excitement above or dimunition below what constitutes the healthy state; and that, whilst physiology assures us there are numerous diversities of functions, each of which has its allotted instrument, it is consistent equally with our knowledge and our ignorance to detect and specify the precise symptoms of their diseases rather than to find "a local habitation and a name" for them in any metaphysical nosology.

The subject of treatment.

The subject of treatment is too technical, for a summary like the present; but a few observations thereon may nevertheless be hazarded. As the brain and nervous system, form an important part of the animal economy, and as they are affected by all the laws which regulate it, their morbid conditions must be treated according to those principles and plans which have been found expedient and serviceable in the maladies of other portions. The peculiar functions with which these parts are endowed, undergo changes which may afford corresponding indications of cure; but the latter cannot be fulfilled by agents possessing specific virtues, nor by any exclusive procedure. For unsound minds, as for fractured limbs, the boldness of quackery has hitherto announced few sovereign remedies; and, believing that there is really none such, experienced physicians have recourse to measures ordinarily available in their profession. They endeavour, according to circumstances, to subdue inflammation, to allay excitement, to remove irritating causes, to counteract depression, to promote digestive action, to regulate the secretions, and excretions, to promote or maintain strength; in short, to establish good physical health, as a requisite (sometimes the only one) to the acquisition and enjoyment of mental sanity. Attention to these points must commence and terminate with the case, which, however obstinate, or seemingly hopeless, ought never to be entirely abandoned, or left to the nostrums of unscientific keepers. Much more, not of a medical character, is frequently necessary, and can only be supplied in appropriate asylums. The benefits to be derived from these are immense, and cannot be too highly estimated. Contrary to a vulgar and unjust prejudice, the features by which they are best known most powerfully recommend them. They offer greater safety than can be secured amidst the erroneous tenderness, the injudicious efforts, the distraction, and often the dreadful apprehensions, of relations and friends;—the retirement and seclusion, which they immediately accomplish, are proved by innumerable undoubted testimonies to be not only conducive, but, in certain cases, necessary, to allay irritability, destroy delusions, and give full effect to professional skill;—whilst, in the control which they exercise, the self-restraint which they cherish, the regularity of habits which they are calculated to generate, the occupation afforded to the strong, the repose and solace to the feeble, the direct supervision and prompt help to all, there is a combination of positive and negative advantages, which not only divests insanity of much of its horrors, by concealing or subduing them, but actually obtains a victory over it scarcely equalled by medicine in any other formidable disease. In some establishments of the kind, the average of recoveries is from sixty to eighty, and even ninety per cent.; that of thirty or forty being reckoned small in our day. Any of these results is gratifying to humanity.

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Errors that prevailed in the treatment of insanity.

As a knowledge of the nature and seat of disease is essential to the adoption of a right method of cure, we can make large allowance for errors which long prevailed in the treatment of insanity. In truth, the works professedly written on this branch of medicine were few; and, before the middle of last century, it obtained comparatively little attention. The remedial measures were at first nearly altogether superstitious. For a long time they seem to have been mostly empirical, or suggested by incidental circumstances. In many instances they must be charged with cruelty, or at least gross want of sympathy; and very few of them, indeed, can be traced to any thing like a just theory either of mind or of the corporeal frame. Convincing proofs of these remarks will be found in the *Traité du Délire*, by Fodéré, to which the reader is referred. Amongst the writers enumerated by this author as deserving of notice, are Cœlius Aurelianus, who reprobated severity, and prescribed on the whole a gentle treatment, both medical and moral; Avicenna, whose employment of emetics, purgatives, bleeding, bathing, and the like, had an appearance of moderation, not a little contrasted, unhappily, by the use of the actual cautery and other harsh measures; Savanarola, a physician of the sixteenth century, remarkable for inculcating a judicious moral procedure, yet practising sundry modes of castigation to an extent scarcely consistent with humanity; Plater, Rivière, Sennertus, and others in the seventeenth century, diligent but rather indiscriminate advocates of what has been styled the antiphlogistic system; Mathiolus and Etmüller, who introduced certain preparations of antimony, with a view to the evacuation of black bile, which was long supposed to be materially concerned in one species of derangement; Wepfer, no less strenuous in his admiration of mercury, which he used with a liberal hand, sometimes combined with opium; and Sydenham, the Hippocrates of England, whose sagacity in detecting diversities of madness was equalled by the appropriateness of his therapeutic efforts, but who does not seem to have had employment enough in this department of his profession to do more than point out the expediency of improvement. This may be said to have been effected gradually, by Mead, Morton, Wedel, Camerarius, Vogel, Lorry, Stoll, and other practitioners, till we reach the days of Willis in England, who, though not a physician, delighted his countrymen and astonished the world by his triumph over this malady, especially in the case of George III., at a period when, judging from prevalent opinions, the idea of success was regarded as almost visionary. His assertion, that nine persons out of ten had recovered, when placed under his care within three months from the attack, excited nearly universal scepticism; and, in allowing his majesty to make use of a razor, whilst he himself stood

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by as a spectator, a great part of the nation, besides being alarmed, saw ground for doubt whether the royal patient or his attendant were the more insane. From this event, though the proportion of cures may have rarely been such as Willis declared, it is certain that medicine has acquired a decided mastery over the class of mental diseases. In proof of what is here stated, we might appeal to the results of practice in numerous establishments, or disclosed by various individuals through the medium of the press; but, instead of naming the most eminent of those who have thus promoted science, we deem it better to narrate an occurrence of high interest, which, in addition to the personal virtue it displays, sets forth the nature of an improvement in which humanity must ever rejoice.

Pinel's method.

In the year 1792, when a system of most barbarous coercion prevailed almost universally in the prisons of maniacs, the elder Pinel, after repeatedly, but vainly, urging that his government would permit the unchaining of patients in the Bicêtre, made personal application to certain authorities for this purpose, and eventually, though with much difficulty, succeeded. He was accompanied in his benevolent visit by Couthon, a member of the commune, who seems to have been rather forced than persuaded into the measure, and whose reluctance was increased when he encountered the horrid noises and wild aspect of the miserable beings upon whom the experiment was about to be performed. "Do with them what you please," said he to Pinel, "but I fear you will be their victim." The only reply was a commencement of the operation, by preparing as many strong waistcoats as might be required instead of the chains hitherto used. Twelve patients being selected for the trial, one of these, reckoned equal to any in ferocity, was an English officer, the particulars of whose history were unknown, save that he had been in fetters forty years, and that in a fit of frenzy he had inflicted a fatal blow on his keeper; a deed which, of course, led to greater restraint, and justified much caution in approaching him. Entering his cell without attendants, and speaking gently, "Captain," said Pinel, "I will order your chains to be taken off, and give you leave to walk in the court, if you will promise to behave well, and not to injure any person." "Yes, I promise," was the answer, "but you only laugh; you are all too much afraid of me." "There are six men at my command, if necessary," rejoined Pinel, "but believe my word, I will give you liberty, provided you put on this waistcoat." The offer was silently but cheerfully accepted, the keepers retired, and the door of the cell was left open. After several attempts to raise himself from a position which had so long cramped his limbs, and having partly succeeded in managing his equilibrium, the captain at length tottered into the free air, when, looking up to the sky, he cried out with enthusiastic delight, "How beautiful!" During the rest of the day he moved about constantly, often expressing the pleasure he experienced; in the evening he went voluntarily to his own cell, where a better couch than he had been accustomed to was prepared for him; and during two years afterwards, he was not only undisturbed by such paroxysms as he had formerly exhibited, but rendered himself serviceable in the management of other patients.

The next subject of experiment proved to be a soldier of the guards, had who been in chains for ten years, and whose case had also called for extraordinary vigilance. Pinel, thoroughly acquainted with his delusions and character, promised the same relief; adding, by way of encouragement, that he should be employed in setting others at liberty, and, on good behaviour, taken into service. The desired effect was realized. Upon being set free, the poor fellow shewed at once his gratitude and obliging disposition; following Pinel with an anxious eye, performing every order given to him, and speaking reasonably as well as kindly to the patients. During the rest of his life, this man continued devotedly attached to Pinel, whose son, the narrator of these affecting incidents, speaks of him with tenderness as a partner in his own childish games.

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In the cases of three Prussian soldiers, who had been chained for many years, though in general calm and inoffensive, the experiment seems to have given them alarm, lest new severities were to be inflicted, and it proved inefficacious, as the patients, either worn out by grief, or having become quite imbecile, were insensible of the blessing conferred upon them. In the instance of a priest, advanced in life, who had displayed religious excitement in one of its most imposing forms, the release from chains, accompanied by a judicious order on the part of Pinel, proved very satisfactory. That able physician directed the attendants, instead of speaking to the patient, to practise his own exalted reserve. The result was such as imprisonment and fetters never did nor could produce. Gradually humbled and brought down to a level with mankind, he mixed in the society of other patients, and, ere a twelvemonth had expired, he was dismissed from the Bicêtre.

Such are a few particulars of a plan of treatment pursued in regard to more than fifty maniacs, of different countries and various conditions, with a success which at once surpassed hope, put the opposite method to shame, and, by its soothing influence, gave to other remedial measures a chance of operating beneficially. We should decline presenting a contrast to the picture, by adducing the horrid disclosures made in England, at a subsequent period by a parliamentary committee, were there not a good purpose to be served by keeping the memory of them alive, as an incentive and admonition.

Report of the committee of 1815.

The report to the House of Commons, dated the 11th of July 1815, commences by stating how sensible the members of the committee were of the importance of the matter entrusted to them, and their earnestness in performing the duty which they had undertaken, assigning the mass of evidence collected as a proof that their inquiries had been extensive. Then follows a sentence which may be liable to animadversion. "It was their intention to make observations in detail on the several heads of the examination taken before them, and on the several public and private establishments for the reception of insane persons; but, on reconsidering the whole subject, they have thought it advisable, in the first instance, to make their report more general." This determination was more prudent than wise; for it may be remarked, first, that the primary intention, if carried into effect, would have been more satisfactory than the course actually adopted; and, secondly, that the reasons for the latter are by no means distinctly specified. The committee were very probably restrained by the consideration that the length of the inquiry had prevented a bill on the subject from being passed during that session. But, be this as it may, the report proceeds thus: "Your committee cannot hesitate to suggest, with the utmost confidence, from the evidence they now offer to the house, that some new provision of law is indispensably necessary for insuring better care being taken of insane persons, both in England and Ireland, than they have hitherto experienced, the number of whom appears to be very considerable, as the inquiries of the committee have convinced them that there are not in the country a set of beings more immediately requiring the protection of the legislature than the persons in this state, a very large proportion of whom are entirely neglected by their relations and friends. If the treatment of those in the middling or in the lower classes of life, shut up in hospitals, private mad-houses, or parish workhouses, is looked at, your committee are persuaded that a case cannot be found where the necessity for a remedy is more urgent." After alluding to some houses, (a few only), in which the arrangement was comparatively good, and the treatment kind, the report proceeds: "But it is in proof, that there is just and great cause

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of complaint against by far the greater part of the houses of this description, which have hardly, in any instance, been built for the purpose, and are incapable of being conveniently adapted to it;" the favourable examples, only four in number, being specified by the committee.

Observations of the committee.

The observations of the committee in support of their general allegation, are then classed under nine heads, as follows, viz.: 1. "Keepers of houses receiving a much greater number of persons in them than they are calculated for; and the consequent want of accommodation for the patients, which greatly retards recovery. They are, indeed, represented by the president of the College of Physicians, and the physician acting as secretary to the visiting commissioners, who must be considered as the most competent judges on the subject, to be better calculated for the imprisonment than the cure of patients." 2. "The insufficiency of the number of keepers, in proportion to that of patients, which unavoidably leads to a proportionably greater degree of restraint than they would otherwise be under." 3. "Mixing patients who are outrageous with those who are quiet and inoffensive; and those who are insensible to the calls of nature with the cleanly." 4. "The want of medical assistance applied to the malady, a point worthy of the most serious attention, as the practice very generally is to confine medical aid to corporeal complaints; which circumstance the committee are the more desirous of enforcing on the house, as an opinion has been given by a respectable physician and another person of great experience, that when the mental faculties are only partially affected, medical assistance is of the highest importance." 5. "Restraint of persons much beyond what is necessary, certainly retarding recovery, even beyond what is occasioned by the crowded state of the house." Of this many instances are given by the committee. 6. This article relates to the situation of parish paupers confined in workhouses, regarding whom the committee made some inquiries, "as connected with the matter before them, although not expressly included in the reference to them." 7. "Detention of persons, the state of whose minds did not require confinement. On this ground of complaint the committee had very slender means of information." 8. "Insufficiency of certificates on which patients are received into mad-houses." 9. "The defective visitation of private mad-houses, under the provisions of the 14 Geo. III. c. 49."

Suggestions of the committee.

After this enumeration, the committee refer to Ireland, as demanding even more urgently than England some further provision for the safety and welfare of insane persons; and, having adverted to other topics, they express themselves as persuaded "that when the extent of the evil pointed out in this report shall be generally known, the visiting physicians in London and its neighbourhood will, as far as the professional calls upon them will permit, give additional attention to the duty they have been desirous of discharging." The committee also trusted that justices of the peace would "watch as narrowly as circumstances would admit, over the conduct of the keepers of houses;" and that magistrates generally throughout the kingdom would think the condition of insane persons worthy of their attention, and convey information to the Secretary of State, if in any case of abuse a prosecution might be deemed requisite." The committee concluded by resolving, "that the chairman be directed to move the house, that leave be given to bring in a bill to amend and enforce the provisions of the act of the 14th Geo. III. c. 49, intituled, "an act for regulating mad-houses."

General remarks

Every one who peruses the evidence produced upon this occasion, must think the report itself less impressive than it might have been made, without any other labour than that of condensing statements and arranging facts. Members of the house, having access to copies, and taking interest in the subject, could no doubt supply its deficiency by the exercise of their own judgment, but at this period the public at large needed to be directly and powerfully roused. Looking, moreover, to the almost total absence of any strong public feeling of indignation regarding flagrant instances of cruelty and systematic mal-administration, one might be tempted to imagine that the committee either had not themselves been convinced by the testimonies before them, or were apprehensive of producing a dangerous excitement throughout the country. The discoveries at York alone, indeed, were enough to inflame one province. But what was the ultimate result? We answer in the words of a journal,[1] which lent its powerful aid in diffusing both knowledge and right feeling over society:—"Under their tranquil but steady guidance, (alluding to the Society of Friends, and to events long previous to the committee's inquiry), a new establishment was formed, that began the great revolution upon this subject, which we trust the provisions of parliament will complete. Their institution, by gentle methods, &c., achieved what all the talents and public spirit of Mason and his friends had failed to accomplish. It had still better effects,—the complete overthrow of the old system."[1] Nay, what was the immediate effect of the appointment of the committee, and the anxiety it displayed? Decided advantage to many sufferers. A speech of Lord Robert Seymour in the House of Commons, penetrated Bethlem Hospital, and produced reformation. But there remained much to be done elsewhere; and the fate of a bill for the better regulation of mad-houses, presented by the committee, showed how difficult was the task to secure complete relief. It passed the Commons, but got no further. It was again brought forward next session, and lost in the Upper House, or, more properly speaking, only postponed, with a view to the rectification of defects then suggested; and, even at the distance of several years, though the legislature interfered, there existed, in various establishments, abuses sufficient to justify the severe reprehensions of another committee.

Scotland and Ireland

Meanwhile, Scotland and Ireland, at different periods and in various ways, received the attention of the legislature. We cannot afford space to treat of what relates to both, or enter upon details respecting either. It is sufficient to say, that an act to regulate madhouses in the former was passed during 1815, and, *inter alia* empowered Sheriffs-depute to make inspections throughout their jurisdictions, and to send reports thereof to two bodies, the Court of Justiciary, and the College of Physicians of Edinburgh; that the duty thus enjoined has ever since been performed with unquestionable benefit, though scarcely known to the public; but that, notwithstanding the good intended or affected by it, one great class of society, in the most unhappy of all circumstances, (namely, pauper lunatics,) is left without adequate provision. The opposition to the bill, proposed for their relief by Lord Haddington, entailed a stigma upon this country, which nothing but the most strenuous exertions, and unwonted liberality, will ever obliterate. Scotland, educated, and enlightened as she pretends to be, and with some justice, is disgraced by the absence of national or provincial asylums for these unfortunates; and, in regard to institutions of the kind, which approximate to a really public character, the metropolis is actually inferior to many of the provincial towns, to Glasgow, Dundee, Perth, Aberdeen, Dumfries, and some others. Of late, however, efforts have been made, by several benevolent individuals to wipe off this reproach; the subject has been examined in all its details; and as inquiry is the certain precursor of improvement, there can be little doubt, we should think, that the principal evils felt and complained of will, ere long, be, in a great measure, corrected. (K. K. K. K.)

[1] See *Edinburgh Review*, vol. xxviii.

Mentor ‖ Menzikoff.

MENTOR, in fabulous history, a faithful friend of Ulysses, a son of Hercules, a king of Sidonia, who revolted against Artaxerses Ochus, and afterwards was restored to favour by his treachery to his allies. (*Diod.* 16.) An excellent artist in polishing cups and engraving flowers on them. (*Plin.* 33, c. 11; *Mart.* 9, ep. 60, v. 16.)

MENTZ, a considerable town of Germany, in the circle of the Lower Rhine, and capital of the late electorate of the same name, is situated on the Rhine near its confluence with the Maine, twenty miles north-west of Worms, fifteen west of Francfort, and seventy-five east of Triers, in E. long. 8. 20. N. lat. 40. 51.

MENTZ, called by the Germans *Mainz* or *Maynz*, and by the French *Mayence*, is a city in the Rhenish province of Hesse-Darmstadt, but is garrisoned and ruled, as far as regards military affairs, by the German confederation. It is situated on the left bank of the Rhine, over which there is a bridge of boats 1720 feet long, connecting it with the fortifications of Cassel. It is one of the most powerful defences of Germany on the side towards France, for besides its walls, it has a citadel and several strong forts, with no less than twenty-seven bastions. It is an ancient city, the Moguntium of the Romans; but though well built in some parts, it is in others in a ruinous state. It is the see of a Catholic bishop, whose cathedral is a very striking object, both from its size and the monuments and other antiquities. It contains eleven other churches, and several public buildings remarkable for their antiquity rather than their beauty. The city contains 2165 houses, and about 25,000 civil inhabitants, of whom one-third are said to be in a state of great destitution. There are a few manufactures on a small scale, but a considerable trade in wine, timber, and other goods, is carried on by the Rhine. The vicinity is fruitful in corn, and produces excellent wine. Lat. 49. 59. 50. N. Long. 7. 35. 40. E.

MENTZEL, CHRISTIAN, born at Frustenwall in the Mittel-mark, is celebrated for his skill in medicine and botany, in pursuit of which he travelled through many countries, and had correspondents in the most distant parts of the world. He died in the year 1701, in about the seventieth year of his age. He was a member of the academy of the *Curieux de la Nature*. His works are, 1. *Index Nominum Plantarum*, printed at Berlin, folio, in 1696, and reprinted, with additions, in 1715, under the title of *Lexicon Plantarum Polyglotton Universale*; 2. *A Chronology of China*, in German, printed at Berlin, in 1696, 4to. The following manuscripts of his composition are preserved in the royal library at Berlin, viz., 1. *Sur l'Histoire Naturelle du Brasil*, in 4 vols. folio; 2. *Sur les Fleurs et les Plantes du Japon*, with coloured plates, 2 vols. folio.

MENUGAT, a small town of Asiatic Turkey, in Caramania. It is situated on a river of the same name, which falls into the Gulf of Satalia, and it is twenty-one miles west of Alanieh.

MENZIKOFF, ALEXANDER, was originally an apprentice to a pastry-cook near the palace of Moscow, but by a fortunate circumstance was drawn from that situation in early life, and placed in the household of Peter the Great. Having made himself master of several languages, and being formed for war and for business, he first rendered himself agreeable, and afterwards became necessary to his master. He assisted Peter in all his projects, and was rewarded for his services with the government of Ingria, the rank of prince, and the title of major-general. He signalized himself in Poland in 1708 and 1709; but in 1713 he was accused of embezzling the public money, and fined in three hundred thousand crowns. The Czar remitted the fine; and having restored him to favour, gave him the command of an army in Ukraine in 1719, and sent him as his ambassador into Poland in 1722. Being constantly occupied with the means of preserving his influence after the death of his master, who was then evidently on the decline, Menzikoff discovered the person to whom the Czar intended to leave the succession. The emperor was highly offended, and his penetration cost him the principality of Plescoff. Under the Czarina Catherine, however, he rose higher in favour than ever, because, upon the death of the Czar in 1725, he was active in bringing different parties in Russia to agree to her succession. This princess was not ungrateful. In appointing her son-in-law Peter II. as her successor, she commanded him to marry the daughter of Menzikoff, and gave the Czar's sister to his son. The parties were actually betrothed, and Menzikoff was made Duke of Cozel and grand steward to the Czar. But this elevation was the prelude to his fall. The Dolgoroukis, favourites of the Czar, had influence enough to procure his banishment, together with that of his family, to one of his own estates, at the distance of two hundred and fifty leagues from Moscow. Having had the imprudence to leave the capital with the splendour and magnificence of a governor going to take possession of his province, his enemies took advantage of this circumstance to inflame the indignation of the Czar. At some distance from Moscow, he was overtaken by a detachment of soldiers, and the officer who commanded them having made him alight from his chariot, which he sent back to Moscow, placed him and his whole family in covered waggons, to be conducted into Siberia, in the habit of peasants. When he arrived at the place of his destination, he was presented with cows and sheep big with young, and poultry, without knowing from whom he received the favour. His house was a simple cottage, and his employment was to cultivate the ground, or to superintend its cultivation. New causes of sorrow were added to the severities of exile. His wife had died on the journey; he had also the misfortune to lose one of his daughters by the small-pox; and his other two children were seized with the same disease, but recovered. He sunk under his misfortunes on the 2d of November 1729, and was buried beside his daughter, in a little chapel which he had built. His misfortunes inspired him with sentiments of devotion, which, amidst the splendour of his former situation, he had altogether neglected.

Meotis ‖ Mequinez.

MEOTIS, or PALUS MÆOTIS, the sea of Azof, which divides Europe from Asia, extending from the Crimea to the mouth of the river Don or Tanais.

MEPHITIC, a name expressing any kind of noxious exhalation, but generally applied to that species of vapour called *fixed air*.

MEPHITIS FANUM, a temple erected near the Lacus Amsancti, to the goddess Mephitis, who was also worshipped at Cremona. Figuratively, *Mephitis* denotes a noisome or pestilential exhalation.

MEQUINEZ, or MIQUINEZ, the northern capital of the empire of Morocco, stands at the extremity of the province of Beni Hassan, eighty leagues north from the city of Morocco (which is the southern imperial city), and twenty to the east of Sallee and the ocean. Maknassa, its founder, built it first at the bottom of a valley; but Muley Ismael extended it considerably over the plain which lies to the west of the valley. It is surrounded with well cultivated fields and hills, adorned with gardens and olive plantations, and abundantly watered with rivulets. The fruitfulness of the soil, and the temperature of the climate, seem to produce even a superior urbanity in the inhabitants. The winter, indeed, is very inconvenient, on account of the dirtiness of the town, the streets not being paved, and the soil being slimy. Mequinez is surrounded with walls; and the palace is fortified with two bastions, on which some small guns were formerly mounted. In this city Muley Ismael and Muley Abdallah often resisted the efforts of the Brebers, the sworn enemies of their tyranny. To the west are seen some walls of circumvallation, six feet in height, which were probably mere intrenchments for the infantry, the attacks of the

Mer || Mercantile law.

Brebers being only sudden and momentary inroads, which did not require a long defence. The houses are neater than those of Morocco, and here, as at Morocco, there is a walled and guarded suburb for the Jews, who are more numerous, and can turn their industry to greater account, than those of the northern capital. Near the Jewry there is another inclosed and separate quarter, called the negro town. It was built by Muley Ismael, for the accommodation of those black families which composed his soldiery, but it is now uninhabited.

At the south-east extremity of the city stands the palace of the emperor, which was built by Muley Ismael. The space occupied by this palace is very great; it includes several gardens, elegantly disposed, and well watered. There is a large garden in the centre, surrounded by a vast and pretty regular gallery resting on columns, which communicates with the apartments. Those of the women are very spacious, and have a communication with a large chamber which looks into the garden. As you pass from one apartment to another, you find at intervals regular courts paved with square pieces of black and white marble; in the middle of these courts is a marble basin, from the centre of which rises a *jet d'eau*, and the water falls down into this basin. These fountains are numerous in the palace; they are useful for domestic purposes, and they serve for the ablutions, which the scruples of the Mahommedans have exceedingly multiplied. The palaces of the Moorish kings are large, because they are composed only of one range of apartments, which are long and narrow, and from eighteen to twenty feet in height; they have few ornaments, and receive the light by two large folding doors, which are opened more or less, as occasion requires. The rooms are always lighted from a square court in the centre, which is generally encompassed with a colonnade.

The Moors here are more courteous than those in the southern parts; they are civil to strangers, and invite them into their gardens, which are very neat. The women are beautiful, and have a fair complexion, with fine black eyes, and white teeth. They are sometimes seen taking the air on the terraces; they do not hide themselves from Europeans, but retire very quickly on the appearance of a Moor.

MER, a town of Hindustan, in the Gulf of Cutch, on the road from Luckput Bunder to Mardanie. The longitude has not been ascertained. Lat. 23. 32. N.

MERAT, a town of Hindustan, in the province of Delhi, situated upon the western bank of the Calcerundy. It has been from ancient times a place of considerable consequence, and is mentioned amongst the early conquests of Mahmoud of Ghizni, in the year 1018. In 1399 it was taken and destroyed by Tamerlane. It was afterwards rebuilt, and when this part of the province came into the possession of the British, it was fixed upon as the capital of one of the districts into which the British possessions in the Doab of the Ganges and Jumna were subdivided. In 1809 it was made one of the principal military stations under the Bengal presidency; it is thirty-two miles N.E. from Delhi. Long. 77. 33. E. Lat. 29. 1. N.

MERBAT, a town of Hadramaut, in Arabia, which carries on a trade in incense; it is thirty-two miles north of Darfur.

MERCANTILE LAW. Amongst the ancient Romans, trade and manufactures were accounted degrading and dishonourable employments; and what was done in that way was performed by slaves. None who had been employed in trade, or whose father had been a slave, could be chosen into the senate; and no senator, or father of a senator, could by law keep a bark above a certain small burthen, in order no doubt to prevent his engaging in commerce. The canonists likewise despised trade; and at the council of Melfi it was solemnly determined that none could exercise any traffic, nor follow the profession of the law, with a safe conscience.

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These notions, however, were singular, and very different from the policy which has ever prevailed in this country. According to a law of Athelstan, if any merchant made three voyages on his own account beyond the British channel, or narrow seas, he was entitled to the privileges of a Thane; and it is specially provided by Magna Charta, (c. 30), that all merchants, unless publicly prohibited beforehand, shall have safe conduct to depart from, to come into, or to tarry in and go through the realm, for the exercise of merchandise, without any unreasonable imposts, except in time of war; and that if a war breaks out between us and another country, the merchants of that place shall be attached, but in their person only, till the king is informed how our merchants are treated in the land with which we are at war, and if our merchants are secure theirs shall be so too. Upon this Montesquieu remarks with admiration, that the English have made the protection of foreign merchants one of the articles of their national liberty; and also that the English know much better than any other people on earth how to value at the same time these three things, religion, liberty, and commerce. These, indeed, are the common rights of mankind. They are also inseparably connected together; and as liberty is the life of commerce, so commerce is in its turn the parent of many advantages, moral and physical, personal and political. Its protection and encouragement are now, therefore, an established principle of the law of nations.

Trade and commerce being thus the immediate offspring of natural liberty, the *lex mercatoria*, or the law of merchants, is less a branch of this or that system of municipal law, than of the law of nations, or that universal law which reason teaches all men. It is, if one may so call it, an ambulatory system of civil law, not confined to any one place or locality, but attaching to the persons of men in all their commercial transactions throughout the world; the custom of merchants being every where acknowledged, as their persons and property are by the law of nations every where protected.

Thus, not to enter here at large into all the details of mercantile law, which will be found in other parts of this work, divers sorts of writings used amongst merchants and trading people in commercial transactions, are sustained in our courts, after the example of other states, although not executed with all the formalities of common deeds. Missive letters, *in re mercatoria*, are valid although not holograph, and commissions from merchant to merchant, though not signed before witnesses; nor do fitted accounts amongst merchants, in mercantile matters, require the writer's name or witnesses. But of all obligations, *bills of exchange*, which owe their origin to merchants, are the most favoured. The risks and accidents of trade have also caused particular favour to be extended to persons engaged therein, who have fallen into bankruptcy; provision being made by statute for their entire discharge, on their surrendering their effects to their creditors.

We find also in many parts of Europe merchant courts or judicatories vested in merchants chosen for that purpose to decide and determine in a summary way their peculiar differences. Of this sort are the guildry courts of the Scottish burghs, which are particularly approved of by statute, 1593, c. 184, as a speedy method of determining all questions between merchant and merchant, and between merchant and mariner, and are declared to have "full strength, force, and effect, according to the lovable form of judgment used in all gude towns of France and Flanders, where burses are erected, and specially in Paris, Roan, Bourdeaux, and Rochelle." Particular attention, indeed, seems to have been paid in Scotland in early times, to the regulation of trade. Before the close of the twelfth century, William the Lion granted to the burgesses of Aberdeen, and the burgesses of Moray, and all his burgesses dwelling north of

Mercator || Mercia.

the Grampians, the privilege of a free *hanse*, or mercantile association, as fully and completely as they had enjoyed the same in time past. In the southern part of the kingdom the court of four burghs had met annually from a remote time; but in addition to this, deputies from the royal burghs south of the Spey were in 1405 appointed to meet in convention with the court of four burghs, to treat, ordain, and determine in all things concerning the utility of the commonweal of the burghs, their liberties and court. The disadvantage, however, of two contemporary assemblies in a country so limited in extent as Scotland, which had also now become a consolidated kingdom, with one common interest, appears to have been quickly felt; for by statute 1487, c. 111, deputies from all the royal burghs, "baith south and north," were appointed to meet in convention, not with the court of four burghs, as before, but by themselves, yearly, to commune and treat upon the welfare of merchandise, the good rule and statutes for the common profit of the burghs, and to provide remedy for all skaith and injury sustained within burghs. Since this enactment, the burghal parliament, or convention of burghs, has continued to our own time.

MERCATOR, Gerard, one of the most celebrated geographers of his time, was born at Ruremonde in 1512. He applied himself with such industry to geography and mathematics, that he is said to have frequently forgotten to eat and drink. The emperor Charles V. had a particular esteem for him, and the Duke de Juliers made him his cosmographer. He composed a chronology, some geographical tables, and an atlas, having engraved and coloured the maps himself. He died in 1594. His method of laying down charts is still used, and bears the name of *Mercator's charts*.

Mercator, *Nicholas*, an eminent mathematician of the seventeenth century, was born at Holstein in Denmark, and came about the time of the Restoration to England, where he lived many years. He was admitted a fellow of the Royal Society, and endeavoured to reduce astrology to rational principles. He published several works, particularly *Cosmographia*. He also gave the quadrature of the hyperbola by an infinite series, which was the first instance in the learned world of a series of this sort derived from the particular nature of the curve, and that in a manner equally new and refined.

Mercator's *Sailing* is that which is performed by Mercator's chart.

MERCATORUM Festum, was a festival kept by the Roman merchants on the 15th of May, in honour of Mercury, who presided over merchandise. A sow was sacrificed on the occasion, and the people present sprinkled themselves with water brought from the fountain called *aqua Mercurii;* the whole concluding with prayers to the god for the prosperity of trade.

MERCHANT, a person who buys and sells commodities in gross, or deals in exchanges; or one who traffics in the way of commerce, either by importation or exportation.

MERCHET (Merchetum), a fine or composition paid by inferior tenants to the lord, for liberty to dispose of their daughters in marriage. No baron, nor military tenant, could marry his sole daughter and heir without such leave purchased from the king *pro maritanda filia;* and many of our servile tenants could neither send their sons to school, nor give their daughters in marriage, without express leave from the superior lord. According to Mr. Astle, the *merchetum* was a compact between the lord and his vassal for the redemption of an offence committed by the vassal's unmarried daughter; and also a fine paid by a sokeman or a villain to his lord for permission to marry his daughter to a free man; but in cases where the vassal gave away his daughter without having obtained this license, he subjected himself to a heavier fine.

MERCIA, the name of one of the seven kingdoms founded in England by the Saxons. Though the latest formed, it was the largest of them all, and grew by degrees to be by far the most powerful. On the north it was bounded by the Humber and the Mersey, which separated it from the kingdom of Northumberland; on the east by the sea, and the territories of the East Angles and Saxons; on the south by the river Thames; and on the west by the rivers Severn and Dee. It comprehended nearly seventeen of our modern counties. Penda is regarded as its first monarch; and the kingdom is thought to have derived its name from the Saxon word *merc*, which signifies a march, boundary, or limit, because the other kingdoms bordered upon it on every side, and not from the river Mersey, as some would persuade us. Penda assumed the regal title in 626, and was of the age of fifty at the time of his accession; after which he reigned nearly thirty years. He was of a most furious and turbulent temper, breaking at different times with almost all his neighbours, calling in the Britons to his assistance, and shedding more Saxon blood than had as yet been spilled in all their intestine quarrels. He killed two kings of Northumberland, three of the East Angles, and compelled Kenwall, king of the West Saxons, to quit his dominions. He was at length slain, with most of the princes of his family, and a multitude of his subjects, in a battle fought not far from Leeds, by Oswy king of Northumberland. This battle, which the Saxon chronicle tells us was fought at Winwidfield in 655, made a great change in the Saxon affairs, which the unbridled fury of Penda had thrown into complete confusion. He had the year before killed in battle Anna, the king of the East Angles, whose brother Ethelred notwithstanding took part with Penda. On the other hand, Penda, the eldest son of Penda, to whom his father had given the ancient kingdom of the Mid Angles, had two years before married the natural daughter of king Oswy, and had been baptised at his court. It should seem that at that time Oswy and Penda were upon good terms; but after the latter had conquered the East Angles, he resolved to turn his arms against the kingdom of Northumberland. Oswy had not provoked this rupture; on the contrary Bede tells us that he offered large sums of money, and jewels of great value, to purchase peace; but these offers were rejected, and he was reduced to the necessity of deciding the quarrel by the sword. The river near which the battle was fought having overflowed, there were more drowned than killed. Amongst these, as the Saxon chronicle says, there were thirty princes of the royal line, some of whom bore the title of kings; and also Ethelred, king of the East Angles, who fought on the side of Penda against his family and country.

Mercia.

His son Penda, who married the daughter of that conqueror, became a Christian, and was not long afterwards murdered, as is stated, by the malice of his mother. His brother Wolfher becoming king of Mercia, embraced in process of time the faith of the gospel, and proved a victorious and powerful monarch; he is commonly styled king of the Anglo-Saxons, though neither he nor his immediate successors are owned in that quality by the Saxon chronicle. But although possibly none of them might enjoy this honour, they were undoubtedly puissant princes, maintaining frequent wars, and obtaining many advantages over the sovereigns of other Saxon states, more especially the East Angles, whom they reduced. The extent of the Mercian territories was so ample as to admit, and so situated as to require the appointment of subordinate rulers in several provinces, to whom, especially if they were of the royal line, they gave the title of kings. Besides establishing episcopal sees and convents, the Saxon monarchs took other methods for improving and adorning their dominions; and as Mercia was the largest, so these methods were most conspicuous in that kingdom. Coventry, as being situated in the centre, was usually, but not always, the royal residence. Penda, who being almost continually in a state of war, lived

Mercura ‖ Mercury.

as his military operations directed, in some town upon the frontiers. Wolfher built a castle or fortified palace for his own residence, which bore his name. Offa kept his court at Sutton Walls, near Hereford.

In each of the provinces there resided a chief magistrate; and if he was of the royal blood, he had usually the title of king. Penda, at the time he married Oswy's daughter, had the title of "king of Leicester." Ethelred made his brother Merowald king of Hereford, and the latter, dying without issue, bequeathed it to his younger brother Mercelm. Similar honours were sometimes conferred upon the princesses; and hence, in Mercia especially, we occasionally read of "vice-queens." By these means the laws were better executed, the obedience of the subjects more effectually secured, and the splendour of the royal residences constantly kept up and augmented.

At length the crown devolving sometimes on minors and sometimes on weak princes, intestine factions prevailed, and the force of this hitherto mighty kingdom began sensibly to decline. Such being the state of matters in the days of Egbert, the most prudent as well as the most potent monarch of the West Saxons, he took advantage of these circumstances; and having encouraged the East Angles to make an attempt for the recovery of their independence, he, at a favourable conjuncture, broke with the Mercians, and after a short war obliged them to submit. But this was not an absolute conquest, the kings of Mercia being allowed by him and his successors to retain their titles and dominions, till the invasion of the Danes put an end to their rule, after this kingdom had subsisted above 250 years. When the Danes were afterwards expelled by the West Saxons, it sunk into a province or rather was divided into many.

MERCURA, a town and fortress of Hindustan in the south of India, province of Mysore, and district of Coorg, of which it is the capital. It was built by Hyder Ally in the year 1773, after he had conquered the country. It is seventy-two miles east from Seringapatam. Long. 75. 58. E. Lat. 12. 30. N.

MERCURY, in the heathen mythology. (See Hermes.) Most of the actions and inventions of the Egyptian Mercury have likewise been attributed to the Grecian, who was said to be the son of Jupiter and Maia, the daughter of Atlas. No one of all the heathen divinities had so many functions allotted to him as this god. He had constant employment both day and night, having been the common minister and messenger of the whole Pantheon; particularly of his father Jupiter, whom he served with indefatigable labour, and sometimes, indeed, in a capacity of no very honourable kind. Lucian is very pleasant upon the multitude of his avocations; and according to the confession of the Emperor Julian, Mercury was no hero, but one who inspired mankind with wit, learning, and the ornamental arts of life, rather than with courage. The pious emperor, however, omits some of his attributes; for this god was not only the patron of trade, but also of theft and fraud. His most magnificent temple stood upon Mount Cylene, in Arcadia. He is described by the poets as a fair beardless youth, with flaxen hair, lively blue eyes, and a smiling countenance. He has wings fixed to his cap and sandals, and holds the caduceus (or staff, surrounded with serpents, with two wings on the top,) in his hand; and is frequently represented with a purse, to show that he was the god of gain. The animals sacred to him, were the dog, the goat, and the cock. In all the sacrifices offered to him, the tongues of the victims were burnt; and those who escaped imminent danger sacrified to him a calf with milk and honey.

Mercury, ☿ in *Astronomy*. (See Astronomy.) This planet is brightest between his elongations and superior conjunction, very near to which last he can generally be seen. He becomes invisible soon after he has found his elongation, going towards his inferior conjunction, and becomes visible again a few days before his next elongation. The brightness of this planet alters sometimes very considerably in twenty-four hours. It has been observed when less than three degrees distant from the sun, and may, perhaps, sometimes be seen even in conjunction with it. Mercury and Venus appear brightest and most beautiful in the opposite parts of their orbits; the former between his elongations and superior conjunction, and the latter between her elongations and inferior conjunction. Therefore, Venus is seen in great perfection as a crescent, particularly in her inferior conjunction, whilst Mercury is seldom seen in such perfect phases. Mercury should be always observed on or near the meridian. When farthest from the sun, he always appears with a very faint light; and when he has a great south declination, or the atmosphere is not perfectly clear, he can seldom be seen in those parts of his orbit, where he only begins to recover his brightness, or where it is much diminished. He has frequently been seen on the meridian even with a telescope of small power; and it appears from the above statement that he may be obscured in a clear day rather more than half his orbit, or nearly one hundred and fourscore days in the year.

Mercury ‖ Mere.

Mercury, in *Heraldry*, a term used in blazoning by planets, for the purple colour used in the arms of sovereign princes.

Mercury Bay, situated upon the north-east coast of the northernmost island of New Zealand, so called by Captain Cook who here observed the transit of Mercury over the sun in 1769. Long. 184. 4. N. Lat. 36. 48. S.

MERCY-SEAT, or Propitiatory, in Jewish antiquity, the covering of the ark of the covenant. The Hebrew name of this cover, which we translate mercy-seat, is *Capporeth*, (Exod. xxv. 17, 22,) from *cappor*, which signifies to cover, to shut up, to expiate, or to pay. This cover was of gold, and at its two ends were fixed the two cherubim of the same metal, which, by their wings extended forwards, seemed to form a throne for the majesty of God, who in Scripture is represented to us as sitting between the cherubim, with the ark itself forming as it were his footstool. It was hence that God issued his oracles to Moses, or to the high priest who consulted him, (Exod. xxv. 22. Numb. vii. 89.)

MERDIN, a city of Diarbekir in Asiatic Turkey, situated upon the top of one of the lofty heights of a mountainous ridge, and commanded by a castle which crowns the summit of the rock. From its situation it is very difficult of access. On the northern side the access is by a narrow pathway which winds amidst rocks and precipices. On the south the road is somewhat better but still very steep, and about a mile and a half in length. The houses are all built of fine hewn stone, and are very old, appearing from the position of the town in a declivity, to rise successively one on the top of another. The works are kept in tolerable repair; but the castle which has a few old pieces of cannon mounted on its towers, is now in a very dilapidated state, having never been completely repaired since the place was taken by Timour. Notwithstanding the elevated situation of the city it has a plentiful supply of the finest water. In the recesses of the mountains the vine is cultivated with success, and wine and considerable quantities of brandy are made by the Armenians. The population of Merdin amounts to 11,000, of which 1500 are Armenians, 200 Jews, the remainder Turks, Arabs, and Kurds. Merdin is the frontier town of the pashalik of Bagdad towards Constantinople, and under the government of an officer appointed by the pasha; it is forty-five miles south from Diarbekir.

MERE a town of the county of Wilts in the hundred of the same name, 102 miles from London. It stands in an angle of the county running into Somersetshire, near a lake or merse, from which its name is derived. It is ill-built,

Meretrix ‖ Merida.

but has an ancient cross which stands in the market-place. The river Stour rises near it. The market is held on Thursday. The population amounted in 1801 to 753; in 1811 to 972; in 1821 to 1151; and in 1831 to 1289.

MERETRIX, amongst the Romans, differed from *prostibula*. The *prostibulæ* were common courtesans, with bills over their doors, signifying their profession, and were ready at all times to entertain customers; the *meretrices* entertained none but at night. The *meretrices* differed in their dress from the matrons. The former wore the *toga* and short tunics, like those of the men; the latter wore the *palla* and the *stola* of such a length as to reach to their feet.

MERIDA, a city of Spain in the province of Estremadura. It is situated on the south side of the river Guadiana, in a strong situation, but by no means in a fruitful country. It was a place of great importance during the prevalence of the power of the Romans in Spain. The monuments left of that people now claim the admiration of all travellers. The circus, the theatres, and a bridge of fifty arches, are still in tolerable preservation, and numerous interesting inscriptions have been discovered amongst the ruins. It contains six monasteries, and 4500 inhabitants.

MERIDA, a province of Colombia in South America. It is bounded on the south by Pamplona and Uarinas; on the north by the lake of Maracaybo; on the west by the province of Maracaybo; and on the east by Truxillo. This province, although in some parts mountainous, and in others unhealthy, has many vallies and plains of extraordinary richness and fertility, yielding in abundance the choicest productions of Colombia. Merida the capital is situated about one hundred and sixty leagues from Caracas, and about one hundred and fifty leagues from Bogota. It stands upon an elevated table land, three leagues in length and one in breadth, is surrounded by three rivers, and unites a fertile soil and temperate climate, with remarkable beauty of situation. It was founded in 1558 under the name of *Santiago de los Caballeros de Merida*, and was once by far the largest city in Venezuela next to Caracas, but having been repeatedly destroyed by earthquakes, it has greatly declined. It is regularly laid out like all the Spanish towns, the streets intersecting each other at right angles, and having each in the centre a clear stream of running water. Being an episcopal city it possesses a cathedral, and there are likewise a convent of nuns, an hospital, a college and other public institutions. By an earthquake which overwhelmed it in 1812, several convents and churches were destroyed, together with a considerable portion of the other buildings. Many of the inhabitants perished in the ruins, nor has Merida entirely recovered from the calamity which then overtook it. The population prior to 1812 amounted to 12,000, but it is now reduced below one-half of that number. Within view of the city the land yields cocoa, coffee, cotton, maize, plantains, and the tropical fruits; together with wheat, barley, and potatoes. In the valley of the Chama, at the foot of the mountains, the temperature is between 89° and 90° of Fahrenheit, whilst immediately fronting the town, the mountains rise into the regions of perpetual snow. The mean temperature of the city is from 67° to 70°, but the vicissitudes of a single day are extreme. The ascent to the city from the valley is by a very steep and narrow pass, and above the plateau on which the city stands, lofty chains of mountains are seen towering on every side. Those to the south are the highest, and their snowy summits are seen rising out of a zone of dark green forests. The number of mountain rivulets affords abundance of water-power for machinery; and should it be found practicable to render the Chama navigable, Merida, from its vicinity to the lake of Maracaybo, would enjoy almost the advantages of a maritime situation. But the excessive insalubrity of that part of the lake where the Chama falls into it is assigned as the reason why the difficulties of the river navigation have not been obviated. In the vicinity of Merida there are said to be mines of gold, but they are not worked. The exceeding fertility of the surrounding country, however, independently of the precious metals, might raise Merida into a place of importance did not its liability to earthquakes prevent its being settled to an extent commensurate with its natural resources. The population of the whole province has been estimated at 50,000.

Meriden ‖ Merioneth-shire.

MERIDEN, a town of the county of Warwick, situated in the hundred of Hemlingford, and ninety-seven miles from London. It is a great posting place, and near to it is the fine house and park of the Earls of Aylesford. The inhabitants were in 1801, 821; in 1811, 817; in 1821, 927; and in 1831, 892.

MERIDIAN, in *Geography*, a great circle supposed to be drawn through any part of the surface of the earth, and the two poles, and to which the sun is always perpendicular at noon. In astronomy, this circle is supposed to be in the heavens, and exactly perpendicular to the terrestrial one.

MERIDIANI, in antiquity, a name which the Romans gave to a kind of gladiators, who entered the arena about noon after the *bestiarii* (who fought in the morning against beasts) had finished. They were so called from *meridies*, noon, the time when they exhibited their shows. The *meridiani* were a sort of artless combatants, who fought man to man, sword in hand. Hence Seneca observes, that the combats of the morning were full of humanity compared with those which followed.

MERIDIONAL DISTANCE, in *Navigation*, is the same with departure, or easting and westing, being the difference of longitude between the meridian under which the ship now is, and any other meridian which she was under before.

MERIDIONAL parts, miles, or minutes, in *Navigation*, are the parts by which the meridians in a Mercator's chart increase, as the parallels of latitude decrease.

MERIONETHSHIRE, a maritime county of North Wales. It is bounded on the north by Carnarvonshire and Denbighshire, on the east by the latter county and Montgomeryshire, on the south by Cardiganshire, and on the west by the Irish Channel. It is of a triangular shape, contracting towards the south. Its length from north to south is thirty-six, and its greatest breadth thirty-four miles. Its area is estimated at 691 miles.

There are few parts of the British Islands in which the scenery is more varied, the surface more irregular, or the prospects more romantic. Many of the peaks of the lofty mountains are near to each other, with deep valleys, or rather chasms between; and in other parts, the variety of objects forming striking contrasts with the vicinity of the sea, give a most picturesque collection of pleasing, though sometimes terrific views. The principal mountains, and their heights above the level of the sea, are Cader Idris, 2914 feet, Arran Fowdy, 2955 feet, Arrening, 2809 feet, Cader Ferwyn, 2563 feet, and Pengarn, 1510 feet. These mountains consist principally of granite, porphyry, and other unstratified rocks, whilst the secondary hills are composed of different kinds of schistus.

The principal rivers are the Dee, which runs through this county, and after passing the beautiful town of Corwin, enters Denbighshire; the Maw or Mawddach, which rises in the middle of the county, and empties itself into the Irish Channel; the Dovy, which rises near a pass in the mountains leading to Montgomeryshire, and forming at last a large estuary, enters the sea at Aberdovy; and the Gleslyn and Dwyrid, which unite their streams before entering the ocean. These rivers receive the waters of numerous brooks and rivulets which trickle from the mountains, and in their course fertilise the valleys through which they run. There are several lakes, of which the most considerable for extent, as well as for beauty, is Llyn Tegid, near Bala, sometimes called Pimblemere. It is about four miles in length, and

Merioneth-shire.

three quarters of a mile in breadth; and its banks are most beautifully adorned with slopes, partly covered with woods, and partly exhibiting verdant pastures. Lynn Talyllin, at the foot of Cader Idris, is less extensive, but scarcely less beautiful. Some fine cataracts add their beauty to the other romantic scenery of this county; of these Rhaidr Dhu and the fall of the Glyn near Port Lyn Dyffws are the most remarkable; but several smaller ones will reward the labour of the traveller who delights in the picturesque.

The agriculture of the county is in a very imperfect state, though the spirited exertions of some large proprietors have recently exhibited specimens of great improvement. Nearly three-fourths of the county is uninclosed, and much even of that part is unproductive waste. Large portions of the marsh lands on the coast have, by inclosing, embanking, and draining, been converted into rich pasture, and much more requires only the application of capital to bring it into the same state. Very little of the land is adapted to the plough, and the principal pursuit of the farmers is breeding and rearing cattle. The heifers from this county are sent in droves to the fairs in the south of England, and when improved by good pasture, are found very valuable beasts. The sheep are of small size, the flesh of them being highly prized, and their wool forms the material for the domestic manufactures.

There are scarcely any manufactures that can be noticed, excepting a few coarse woollens; the females of all the families, however, employ themselves in knitting hosiery goods from the native wool. These furnish considerable quantities of the caps called Welsh wigs; and gloves, and stockings, the only goods that are sent out of the county, and the annual value of which is estimated at £25,000. The only trade is from the harbour of Barmouth, situated on a small arm of the sea, into which several rivulets empty themselves. The port is difficult of entrance, and but little frequented. It is chiefly devoted to the coasting trade; exporting oats, barley, butter, cheese, oak-bark, and timber, and importing coals, culm, and groceries. On account of the excellence of the beach, and the romantic beauties of the surrounding country, it has been much frequented of late years for sea-bathing.

The number of the inhabitants at the several decennial enumerations has been found to stand thus: in 1801, 27,500; in 1811, 30,924; in 1821, 34,362; and in 1831, 35,315. At this last period the males were 17,194, and the females 18,121. In the year 1830 the baptisms were of males 254, and of females 284, being a total of 538. The burials of the same year were of males 275 and of females 277, being a total of 552. The marriages were 255. The illegitimate births were of males, eight, and of females thirteen. The families were 7358, of whom 3583 were chiefly employed in agriculture, 1815 in trade, manufactures and handicraft, and 1960 were not comprehended in either of the preceding classes. The males twenty years of age were 8879. The occupiers of land employing labourers were 1112 and those not employing labourers were 1246. The labourers were 2601. The persons employed in manufactures or in making manufacturing machinery were 194; those engaged in retail trade or in handicraft as masters or workmen were 1761; the capitalists, bankers, professional, or other educated persons, were 146; and the labourers employed in other than agricultural labour were 738, and the other males twenty years of age were 998. The male servants were 131, and the female 2222. The annual value of the real property of the county, as assessed for the purpose of the income tax in 1815, was £111,436.

The towns of most consideration are Dolgelly, where the assizes are held with 4087 inhabitants; Llanghill, with 2359; Corwen, with 1980; and Festeniog, with 1648. The most remarkable seats are those of Sir Robert Williams Vaughan, at Nannau; of Mr. Oakley, at Tany Bwlch Hall; Sir Thomas Mostyns, at Cors y Gedel, and Mr. Corbet at Ynysymaengwyn. One member is returned to parliament for the county.

Merlin ‖ Meroe.

MERLIN, Ambrose, a famous English poet and reputed prophet, who flourished at the end of the fifth century. Many surprising and ridiculous things are related of him, and several English authors have represented him as having transported from Ireland to England the great stones which form Stonehenge on Salisbury plain. Extravagant prophecies have also been attributed to him.

MERMAID, or Merman, a sea-creature frequently talked of and supposed to be half human half fish. However naturalists may doubt of the existence of *mermen* or *mermaids*, there is abundance of testimony in its favour; but the authenticity and value of that testimony presents a different question. In the year 1187, Lary informs us that such a monster was fished up in the county of Suffolk, and kept by the governor for six months. It bore so near a conformity to man, that nothing seemed wanting to it but speech. One day it took the opportunity of making its escape; and plunging into the sea, was never more heard of. (*Hist. d'Angleterre*, p. i. p. 403.) In the year 1430, after a huge tempest, which broke down the dykes in Holland, and made way for the sea into the meadows, some girls of the town of Edam in West Friesland, having gone in a boat to milk the cows, perceived a mermaid embarrassed in the mud, with very little water. They took it into their boat, and brought it with them to Edam, dressed it in woman's apparel, and taught it to spin. It fed like one of them, but could never be brought to attempt speech. Some time afterwards it was brought to Haerlem, where it lived for some years, although still shewing an inclination to the water. (*Delices de Hollande.*) In Pontopidan's Natural History of Norway, we have also accounts of mermaids, but not more remarkable nor any way better attested than the above, to which we have given a place, merely to shew how far the folly and extravagance of credulity have sometimes been carried by weak minds.

MERNITCH, a town of Hindustan in the province of Bejapoor, situated on the banks of the Krishna, and formerly the capital of a Hindu principality, and afterwards the capital of different Mahratta chieftains. It was taken by Hyder in 1778. Long. 75. E. lat. 16. 56. N.

MERNS, Mearns, or Kincardineshire, a county of Scotland. See Kincardineshire.

MERODACH, an ancient king of Babylon, who was placed amongst the gods, and worshipped by the Babylonians.

MEROE, the name of an island included between the main branch of the Nile and the Astaboras or Tacazzé, and also that of the capital of Ethiopia, (see Ethiopia), which was situated in this island. Agatharcides, Strabo, Diodorus, and others make mention of Meroe, and communicate several particulars respecting it. The island is stated by Diodorus to be 375 miles in length, and 125 miles in breadth. The exact distance of Meroe from Syene or Assouan, appears to have been a subject of dispute even in Pliny's time, notwithstanding that a number of travellers had already visited and even penetrated beyond the capital of Ethiopia. Delion is mentioned as having travelled far beyond Meroe, which was afterwards visited by Aristocreon, Bion, Basilis, and Simonides the younger, who is said to have written an account of the city. Timosthenes spent sixty days in making the journey by water; Eratosthenes reckoned the distance 625,000, and Artemidorus 600,000 paces; Bion gives a list of towns but no distances. The sixty days' journey or sail by water, however, is too indefinite a datum to be of any use, although it agrees tolerably well with the account given by Herodotus. But the 625,000 paces of Eratosthenes are about the length of the direct caravan route; and the 600,000 paces of Artemidorus, agree still more closely with the ascertained length of that route, across the Great Desert by Korosko and Abu-Hammed, which is

Meroe.

560 miles. According to Pliny, the dispute concerning the distance from Syene to Meroe was finally settled by the pretorians and tribune sent by Nero to explore the country, and who calculated it at 876,000 paces, and on the supsition that these men followed the sinuosities of the river, in order to observe the towns, and report upon the resources of the country, this is pretty near to the truth. Pliny computes the distance from Napata to the island of Meroe at 360,000 paces, and further states that, from the commencement of the island to the site of the town, it is 70,000 paces, the actual distance being about 60 miles. The difficulty here, however, is to ascertain the position of the ancient Napata, which has been fixed by some at Gibel-el-Birkel, and by others at Old Dongola, whilst Ptolemy places it much farther to the north. In fact, Gibel-el-Birkel is nearer to Meroe than the ancient Napata by about 100 miles, that is, reckoning from Pliny's computation of the distance of the latter as compared with that of the former place, which has been ascertained by modern travellers; and hence the presumption is in favour of the accuracy of Ptolemy, who, as we have just mentioned, places the site of Napata farther to the north. That geographer, moreover, places the capital of Ethiopia in latitude 16° 26′, which differs only by 30′ from the latitude as determined by the observations of Caillaud. All that remains of ancient Meroe is its magnificent necropolis, as it has been called, crowded with pyramids, of which a very full and interesting account is given in Hoskins's *Travels in Ethiopia*. "The pyramids of Djizeh are magnificent," says this traveller, "wonderful from their stupendous magnitude; but for picturesque effect and elegance of architectural design, I infinitely prefer those of Meroe. I expected to find few remains here, and certainly nothing so imposing, so interesting as these sepulchres doubtless of the kings and queens of Ethiopia. I stood for some time lost in admiration. From every point of view, I saw magnificent groups, pyramid rising behind pyramid, while the dilapidated state of many did not render them less interesting, though less beautiful as works of art." From motives of curiosity or perhaps avarice, attempts have been made to open many of the pyramids, but without success. In those which had been partially broken into Mr. Hoskins did not perceive the slightest indication that any of them contained galleries; a circumstance which does not appear to favour his opinion that they were places of sepulture. There is no doubt, however, that these pyramids belong to a very remote age, and form a subject of interesting investigation, with reference to the question whether the Ethiopians derived their knowledge of the arts from the Egyptians, or the Egyptians from the Ethiopians. (See Ethiopian Nations.) The hieroglyphics are much defaced, and inferior in grouping or arrangement to those in the Egyptian inscriptions, being, according to the view which may be taken of the course of civilization, either a corruption of the Egyptian style, or the source whence it was originally derived. As to the city of Meroe itself, with its temples and palaces, scarcely a trace or vestige remains. A large space about 2000 feet in length, and at the same distance from the river, being strewed with burned bricks, some fragments of walls and stones similar to those used in the construction of the pyramids, is supposed to have formed part of the site of the capital; and this idea is strengthened by the remark of Strabo, that the walls of the habitations were built of bricks. As at Memphis, however, scarcely a trace of a palace or temple is to be seen, the very ruins of these edifices having perished. This once populous plain is now occupied only by herds of timid gazelles, whilst hyenas and wolves abound in the neighbouring hills. For an account of the history, arts, and commerce of Meroe, see the article Ethiopian Nations, and also Hoskins's *Travels*, (chapters xix, xx, xxi, and xxii.)

Merope ‖ Mersey.

MEROPE, in *Fabulous History*, one of the Atlantides, who married Sisyphus the son of Æolus, and like her sisters was changed into a constellation after death.

MEROPS, in *Fabulous History*, a king of the island of Cos, who married Clymene, one of the Oceanides. He was changed into an eagle, and placed amongst the constellations. A celebrated soothsayer of Percosus in Troas, also bore the name of Merops.

MERS or Merse, a county of Scotland, called also *Berwickshire*. This last name it derives from the town of Berwick, which was the head of the shire before it fell into the hands of the English, and obtained the appellation of *Mers* or *March*, because it was one of the borders towards England. See Berwickshire.

MERSEBURG, one of the departments into which the Prussian government of Saxony is divided. It is formed out of a part of the dominion of the kingdom of Saxony, and several divisions which, before the late war, belonged to Prussia, and is now a compact territory, though some portions of the country of Saxe-Weimer and of Bernburg are mixed with and surrounded by it. The extent of the government is 4114 square miles, and in 1826 it contained 565,632 inhabitants, in sixty-nine cities or walled towns, eleven market towns, and 1648 villages and hamlets. It is divided into seventeen circles, one of which is of the same name as the government, and contains the capital and the district around it. This capital is situated upon the river Saal, at the point where the Geisalbach falls into that stream; it is surrounded with walls, and though old is well built. The dome, or cathedral church, is celebrated as the burial-place of the Emperor Rudolph of Swabia, of Bishop Dittmar, one of the oldest of the German authors, and other eminent persons; and also on account of an organ of great power, with 4000 pipes. There are three parochial churches, an orphan house, workhouse and hospital, 1895 dwellings, and 8056 inhabitants. There are also several institutions for education, especially an endowed grammar school. It contains some cloth manufactories, some tanneries, and extensive distilleries. Lat. 51. 21. 35. N. Long. 11. 54. 15. E.

MERSENNE, Marin, a learned French author, born at Oysé, in the province of Maine, in the year 1588. He studied at La Flèche at the same time with Descartes, with whom he contracted an intimate friendship, which lasted till death. He afterwards went to Paris, and studied at the Sorbonne; but in 1611 he entered himself amongst the Minims, and became well skilled in Hebrew, philosophy, and mathematics. He was of a tranquil, sincere, and engaging temper; and was universally esteemed by persons illustrious for their birth, their dignity, and their learning. He taught philosophy and divinity in the convent of Nevers, and at length became superior of that establishment; but being anxious to apply himself with more freedom to study, he resigned all the posts he enjoyed in his order, and travelled into Germany, Italy, and the Netherlands. He wrote a great number of excellent works, the principal of which are, 1. Questiones celeberrimæ in Genesim; 2. Harmonicorum libri; 3. De Sonorum natura, causis, et effectibus; 4. Cogitata physico-mathematica; 5. La Vérité des Sciences; 6. Les Questions inouies. He died at Paris in 1648. He had the reputation of being one of the best men of his age. No person was more curious in penetrating into the secrets of nature, and carrying all the arts and sciences to their utmost perfection. He was in a manner the centre of all the men of learning, by means of the correspondence which he carried on with them. He omitted no means of engaging them to publish their works; and the world is obliged to him for several excellent discoveries, which, had it not been for him, would perhaps have been lost.

MERSEY, a river of England, which runs through the counties of Lancaster, York, and Chester, and empties itself

Mersey ‖ Merville.

into the Irish Sea at Liverpool. By means of inland navigation, it has communication with the rivers Dee, Ribble, Ouse, Trent, Derwent, Severn, Humber, Thames, Avon, &c.; a navigation which, including its windings, extends above 500 miles, in the counties of Lincoln, Nottingham, York, Lancaster, Westmoreland, Chester, Stafford, Warwick, Liecester, Oxford, Worcester, &c.

MERSEY *Island*, an island of Essex, at the mouth of the Coln, south of Colchester. It was seized by the Danes in the reign of king Alfred, for their winter quarters. It had eight parishes, which are now reduced to two, viz. East and West Mersey.

MERTHYR TYDVIL, a large town of the county of Glamorgan and hundred of Narberth, in South Wales, 184 miles from London, and 24 from Cardiff. From a small village it has, in a few years, since a canal navigation has been opened with the sea at Cardiff, risen from a small village to a large and populous town. This progress has been made by the great improvement which has been introduced in the fabrication of iron, the ore of which, as well as abundance of coal, is found in vast quantities. The machinery of the principal works, especially the overshed wheels, is of stupendous power, and one is turned by a stream of water brought by artificial means from hills at five miles distance. The cast and forged iron that is made in this place amount to many hundred tons weekly, and with the contingent occupations gives employment to thousands of individuals. It has well supplied markets on Wednesday and Saturday. From its population and wealth it has by the Reform Act acquired the privilege of returning one member to the House of Commons. The population in 1801 amounted to 7,705; in 1811 to 11,104; in 1821 to 17,404; and in 1831 to 22,083.

MERTON, a town in the county of Surrey and hundred of Brixton, seven miles from London. It is situated on the river Wandle and celebrated for its calico printing, which is considered as the most perfect both in design and execution of any produced in England. The college of the same name at Oxford was originally founded here and removed to that city in 1274, at the end of ten years. The great Lord Nelson was a resident of this place. The population in 1801 amounted to 813; in 1811 to 905; in 1821 to 1177; and in 1831 to 1447.

MERUD, also named Amrarati, a large town of Hindustan in the province of Bejapoor, inclosed with a high wall, and commanded by a fort. It is forty-four miles south-east from Poonah. Long. 74. 86 E. Lat. 18. 15. N.

MERU SHAH TEHAIN, a city of Khorassan in Persia, capital of Murgiana, founded by Alexander the Great, and afterwards embellished by Antiochus Nicator, who gave it the name of Antiochia. It is situated on the river Murgab, the waters of which were raised by a dyke for the supply of the city. It was one of the four imperial cities of Khorassan, and was long the seat of many of the sultans of Persia, particularly of three of the Seljukian dynasty. The walls were at that time surrounded on all sides with stately palaces, groves, and gardens; and the fruits were reckoned superior to those of any other place. Alp Arslan the most powerful prince of his time, reigned here in all the splendour of oriental magnificence. This great capital was taken and pillaged by the Usbecks about the year 1793, since which time it has been gradually declining; and its inhabitants do not amount to more than 3000, under the rule of an independent chief, the brother of the ruler of Bokhara, whose territories extend several days' journey round. It is 130 miles N.E. of Meshed.

MERVILE, a city of the department of the north and the arrondisement of Hazebrouch in France. It is situated on the left bank of the river Lys and contains 700 houses, 5700 inhabitants, who refine salt, prepare snuff, and make some cloths.

MESCHTSCHOWSK, a circle of the Russian province of Kaluga, extending over 684 square miles, and containing 78,600 inhabitants. The capital is a town of the same name, 648 miles from St. Petersburg, on the river Tureja, with 360 houses, and 1830 inhabitants. Lat. 44. 22. N. Long. 34. 55. E.

Meschtschowsk ‖ Mesopotamia.

MESEN, a circle in the Russian province of Archangel, extending from 63. 2. to 68. 10. N. lat., and from 37. to 44. 25. E. long. Except in the southernmost part it is very little capable of cultivation, and contains but a very thin population, in a rude state of bare existence. The capital is a city of the same name, situated at the mouth of the river Mesen, which forms a convenient harbour, in lat. 65. 16. 30. N., and long. 44. 18. 55. E. It contains 1850 inhabitants, chiefly employed in the fisheries.

MESFAGNA, a town of the province of Otranto, in the kingdom of Naples, the capital of a district of the same name, between Taranto and Brindisi, on the great road. It contains 5200 inhabitants.

MESHED ALI, or NESJIFF, a celebrated town of Irak Arabi, and a holy city, the supposed burying place of the caliph Ali, situated on a hill at the bottom of an artificial lake, twenty-five miles from Hilleh and four miles from Kufa. This city was founded by Alexander the Great and for a long time bore the name of Alexandria which was afterwards changed into that of Hira, when it became the residence of an Arabian dynasty of princes, who fought under the Parthian banners against the emperors of Rome. It was governed by christian princes till the year 632, when it was taken by Kaled the Saracen general, who put to death the last of the race. It is a well built town, defended by a good wall, deep ditch, and lofty towers, which were renewed in consequence of the dread of an attack from the Wahabbees. The tomb of Ali, which fills an ample space in the middle of the city, is a monstrous structure, encircled by a high wall, within which it is death for an infidel to penetrate. The dome is light and elegant and was gilded by order of Nadir Shah. The town is supported by an influx of pilgrims who come to adore at the shrine of Ali. The environs are arid and barren, and are rendered still more gloomy by the numerous graves of Persian fanatics who order their remains to be transported hither from the most remote parts of Persia. The town was formerly supplied with water by an aqueduct which was destroyed by the Wahabbees; so that Colonel Kinneir, who was here in 1808, mentions that a supply of water had to be brought to the city from a distance of three miles in sheep skins. It is 90 miles south of Bagdad.

MESN, or MESNE, a term in law, signifying him who is lord of a manor, and so has tenants holding of him, whilst he himself holds of a superior lord. The word is properly derived from *maisne, quasi minor natu*, because his tenure is derived from another, from whom he holds.

MESOCHORI, were musicians amongst the ancients, who presided in concerts, and by beating a wooden desk regularly with their feet, directed the measure of the music. For the purpose of beating time they wore wooden clogs, called by the ancients *crupezia*, which caused the sound to be better heard.

MESOPORPHYRON, a name given by the Greeks to the Roman *laticlave*, because that garment being edged on each side, where it opened before, with purple, appeared when closed with two purple stripes down the middle. The same term was also applied to the *augusticlave*.

MESOPOTAMIA, the ancient name of the province of Diarbeck, in Asiatic Turkey. It is situated between the rivers Euphrates and Tigris, having Assyria on the east, Armenia on the north, Syria on the west, and Arabia Deserta, with Babylonia, on the south. The Hebrews called it *Padan-aram*, and *Aram Naharaim*, or Aram of the two rivers, because it was first peopled by Aram father of the

Mesopterycius ‖ Messiah.

Syrians, and is situated between the two rivers already mentioned. This country is much celebrated in Scripture, as being the first dwelling of men both before and after the deluge; and because it gave birth to Phaleg, Heber, Terah, Abraham, Nahor, Sarah, Rebekah, Rachel, Leah, and to the sons of Jacob. Babylon was in the ancient Mesopotamia, until, by vast labour and industry, the two rivers of the Tigris and the Euphrates were united into one channel. The plains of Shinar were in the same country. They often gave it the name of Mesopotamia, and sometimes that of Syria, (Hosea xii. 12).

MESOPTERYCIUS, a term applied to such fishes as have only one back-fin, which is situated in the middle of the back.

MESPILUS, the Medlar, a genus of plants, belonging to the icosandria class, and in the natural method ranking under the thirty-sixth order, *Pomaceæ*. See Botany.

MESS, in a military sense, implies a number of soldiers, who, by laying up a certain proportion of their pay towards provisions, mess together. Experience proves that nothing contributes more to the health of a soldier than a regular and well chosen diet, and his being obliged every day to boil the pot. It corrects drunkenness, and in a great measure prevents gaming and desertion.

MESSALINA, Valeria, a daughter of Messala Barbatus. She married the emperor Claudius, and disgraced herself by her cruelty and incontinence. Her husband's palace was not the only seat of her lasciviousness, but she prostituted herself in the public streets, and few men there were at Rome who could not boast of having enjoyed the favours of the impure Messalina. Her extravagancies at last irritated her husband, who commanded her to appear and answer all the accusations which were brought against her. Upon this she attempted to destroy herself; and when her courage failed, one of the tribunes who had been sent to her despatched her with his sword. It is in speaking of her lewdness and debaucheries that Juvenal says,

Et lassata viris, necdum satiata, recessit.

Her name has become a common appellation to denote a woman of shameless and inordinate profligacy.

MESSANA, in *Ancient Geography*, the first town of Sicily on crossing over from Italy; it is situated on the strait now called the *Faro*.

MESSENA, or Messene, an inland town, the capital of Messenia, a country of Peloponnesus, erroneously placed by Ptolemy on the coast. It was built by Epaminondas, who recalled all the Messenian exiles, and gave to the town the name of *Messene*, a place vying in point of strength and situation with Corinth; and hence Demetrius Phalereus advised Philip, father of Perseus, if he wanted to have the Peloponnesus in his power, to make himself master of these two towns, and thus he would have the ox by both horns.

MESSENIA, a country in the south of Peloponnesus, mostly maritime, being situated between Elea to the west, and Laconia to the east. This country is famous in history, on account of the resistance made by the Messenians against the Spartans, and the exploits of their hero Aristomenes.

MESSIAH, a word signifying one "anointed," or installed into an office by "unction." It was usual amongst the Jews to anoint kings, high priests, and sometimes prophets, at their designation or installment, to signify emblematically the mental qualifications necessary for discharging those offices. Saul, David, Solomon, and Joash, kings of Judah, received the royal unction; Aaron and his sons received the sacerdotal, and Elisha the disciple of Elijah, received the prophetic unction. The name Messiah, *Anointed*, or *Christ* (Χριστος), was given to the kings and high priests of the Jews. The patriarchs and prophets are also called by the name of *Messiahs*, or the *Lord's anointed*. (See 1 Sam. xii. 3, 5. 1 Chron. xvi. 22. Ps. cv. 15.)

But this name Messiah was principally and by way of eminence, given by the Jews to their expected deliverer, whose coming they still wait, and is a name which the Christians apply to Jesus Christ, in whom the prophecies relating to the Messiah were accomplished. The sum of these prophecies is, that there should be a glorious person named *Messiah*, descended from Abraham, Isaac, and Jacob, who should be born at Bethlehem, of a virgin of the family of David, then in its decline, before the Jews ceased to be a people, whilst the second temple was standing, and about five hundred years after Ezra's time, and who, though appearing in mean circumstances, should be introduced by a remarkable forerunner, whose business it would be to awaken the attention and expectation of the people. That this illustrious person called *Messiah* should himself be eminent for the piety, wisdom, and benevolence of his character, and the miraculous works he should perform; yet that, notwithstanding all this, he should be rejected and put to death by the Jews, but should afterwards be raised from the dead, and exalted to a glorious throne, upon which he should through all generations continue to rule, at the same time making intercession for sinners. That great calamities should for the present be brought upon the Jews for rejecting him, whereas the kingdom of God should by his means be erected amongst the Gentiles, and disperse itself even unto the ends of the earth, destroying idolatry, and establishing true religion and righteousness. In a word, that this glorious person should be regarded by all who believed in him as a divine teacher, an atoning sacrifice, and a royal governor, by means of whom God would make a covenant with his people, very different from that which he had made with Israel of old, and in consequence of which they should be restored to, and established in, the divine favour, and fixed in a state of perpetual happiness. (See Jesus Christ.)

The Jews, as was already observed, still wait for the coming of the Messiah, being impressed with the notion of a temporal Messiah, who is to be a mighty conqueror, and to subdue all the world. Most of the modern rabbin, according to Buxtorf, believe that the Messiah has already come, but that he keeps himself concealed, and will not manifest himself because of the sins of the Jews. Some of the Jews, however, in order to reconcile those prophecies which seem to contradict each other as to the character and condition of the Messiah, have had recourse to the hypothesis of two Messiahs, who are yet to succeed each other; one in a state of humiliation and suffering, and the other in a state of glory, splendour, and power. The first, they say, is to proceed from the tribe of Ephraim, who is to fight against Gog, and to be slain by Annillus, (Zech. xii. 10.) The second is to be of the tribe of Judah, and lineage of David, who is to conquer and kill Annillus, and restore the kingdom of Israel, reigning over it in the highest glory and felicity.

Messier.

MESSIER, Charles, a celebrated astronomer, born at Badonviller, in Lorraine, on the 26th of June 1730. He was the tenth of twelve children, and lost his father when he was eleven years old. He came to Paris at twenty, and had then to seek his fortune, having only learned to write a good hand, and to draw. Delisle employed him as a copyist in the observatory. Libour, his secretary, taught him to make use of the common instruments of astronomy, to observe eclipses, and to look out for comets; and this was the principal business of his subsequent life, for he was never much of a theoretical or philosophical astronomer. Delisle obtained for him an appointment as clerk in the Hydrographical Department of the Navy, and gave him his board and lodging in his own house; and he claimed in return the singular gratification of keeping all Messier's observations of comets secret for his own private amusement, until their novelty was completely lost.

Messier.

Messier had already discovered twelve comets when he lost his wife; his attendance on her sick-bed prevented his discovering a thirteenth; and it is said that the circumstance added not a little to his grief for her loss. He afterwards became Astronomer to the Navy, instead of being only a clerk in the department. He obtained a seat in the Academy with some difficulty, and not till 1770, being considered as too mechanical an observer to have a very strong claim to that distinction. He was fond of drawing charts of the paths of comets, and of other astronomical phenomena. One of these procured him the honour of being made an Academician of Berlin, and another, with Laharpe's interest, obtained him the same distinction from Petersburg. He was also made a Fellow of the Royal Society of London, in 1764. The highest compliment that he ever received was paid him, perhaps without sufficient reason, by Lalande, who inserted, in his celestial globe of 1775, a constellation with the name of Messier, or *Messium custos*, The Harvest Man, in the neighbourhood of Cepheus. When Herschel had discovered the Georgian planet, he was very diligently engaged in observing its motions; but, in the meantime, his studies were interrupted by an unfortunate accident. He fell into an ice-house, in a garden, which he mistook for a part of a grotto, and fractured an arm and a thigh. He was long in recovering, and he obtained a small pension on the occasion, from the royal bounty, by the solicitations of M. Sage and some others of his friends, who had interest; of this, however, he was soon after deprived by the Revolution. Messier was in some measure compensated for his pecuniary losses by being made a Member of the Institute, of the Bureau des Longitudes, and of the Legion of Honour. He lived to be near eighty-seven, and died of a dropsy, or probably rather of old age, on the 11th of April 1817. The following is a list of his works:—

1. A variety of his observations, especially of *Comets*, are published in the *Mémoires des Savans étrangers*, v. vi. 2. After his admission into the Academy, he was a constant contributor to its *Memoirs* from 1771 to 1790. His papers consist almost entirely of *Observations of comets and eclipses*, with some *Accounts of Aurorae Boreales*. There is also a *Catalogue of Nebulae* in 1771; *An Account of points of light seen on Saturn's ring* in 1774; and of *An apparent fall of globules over the sun's disc*, 1777. 3. In the *Connaisance des Temps* there is a collection of his *Observations of the eclipses of Jupiter's satellites*. 4. He contributed some articles to the *Astronomical Ephemerides*, of Professor Hell, published at Vienna. 5. The *Voyage de Courtanvauz sur la frêgatte l'Aurore*, Paris, 1768, in 4to. was written by Pingré; the observations are Messier's. 6. His only separate publication, (the genuineness of which, however, is doubted,) was entitled *Grande Comète qui a paru à la naissance de Napoléon le Grand*, Paris, 1808, in 4to. 7. Delambre was in possession of a number of his *unpublished* observations of the solar spots; but he found their results when computed, somewhat unsatisfactory.

MESSINA, an intendancy or province of the island of Sicily, including the northern part of the Val de Demone, extending to the foot of Mount Ætna. It is bounded on the north and the east by the sea, on the south by the province of Catania, and on the west by that of Palermo. It is divided into four provinces, viz., Messina, Castroreale, Mistretta, and Patti, and contains 326,674 inhabitants. The capital is the city of the same name, situated partly on a plain, and partly on the side of a hill overlooking the narrow Faro of Messina, and the province of Calabria on the continent. The harbour is capable of containing one thousand sail of vessels; and as the entrance is narrow, and protected by strong batteries, it was found an admirable position for a British force, whilst the opposite continent was in possession of the enemy. The city is surrounded by an old and irregular wall. It contains a fine Gothic cathedral, and many other churches, and several monasteries. Within the walls the houses are 9000, with 61,000 inhabitants, but including the several villages adjoining, the population is 73,000. It has some considerable manufactures of silk goods and an export trade in silk, oranges, citrons, oil, wine, and silk stuffs.

Messuage || Metaphrast

MESSUAGE, Messuagium, in *Law*, a dwelling-house, with some land adjoining assigned for its use. Under the name of messuage may be included a garden, shop, mill, cottage, chamber, cellar, or the like. In Scotland, messuage denotes what is called in England the *manor-house*, or the principal dwelling-house within any barony.

MESTRE, a market town, the chief place of a district in the delegation of Venice, in Italy. It stands on the Marcenigo, contains many small houses, inhabited by 5320 persons, who are mostly carriers or gondoliers. It is in lat. 45. 29. 6. N. Long. 11. 44. 40. E.

META, in the Roman circus, was a pile of stones of a pyramidical form, intended as the boundary of the *stadium*, or chariot course. When the *meta* had been passed the seventh time, the race was concluded. The greatest art and management were required in avoiding the *meta*, and yet going as near it as possible. If they went too near, they were in the greatest danger of breaking the chariot to pieces; and if they took too large a circuit in the turn, they gave their rivals an opportunity of getting within them, besides losing a great deal of ground. The *metæ* at Rome were first of wood, and afterwards of stone; but the emperor Claudius made them of gold, or rather gilded them. In the Roman circus there were two *metæ*, one at the entrance of the course, and the other at the end of it. An egg was placed upon the top of each of the *metæ*.

METAGITNION, the second month of the Athenian year, answering to the latter part of our July and the beginning of August, and so called from *metagitnia*, a festival in honour of Apollo, which was observed in that month.

METAL is a substance which is distinguished from others by its ductility, malleability, tenacity, &c.

METALLURGY, in a general sense, comprehends the whole art of working metals: and in this acceptation, essaying, smelting, refining, parting, smithery, gilding, and so forth, are only branches of metallurgy. But in a more limited sense it includes only the operations which are followed in separating metals from their ores.

METAMORPHOSIS, in general, denotes the changing of something into a different form. In this sense it includes the transformation of insects, as well as the mythological changes related by the ancient poets.

METAPHOR. In poetry a metaphor differs from a simile in form only not in substance. In a simile the two subjects are kept distinct in the expression, as well as in the thought; in a metaphor, the two subjects are kept distinct in the thought only, not in the expression. An *allegory* differs from a metaphor; and a *figure of speech* differs from both. An allegory is one thing figured to be another; it consists in choosing a subject having properties or circumstances resembling those of the principal subject; and the former is described in such a manner as to represent the latter. In a *figure of speech*, there is no fiction of the imagination employed, as in a metaphor; nor a representative subject introduced, as in an allegory. It regards the expression only, not the thought, and may be defined, the using a word in a sense different from what is proper to it.

METAPHRAST, a translator, or a person who renders an author word for word into another form or another language.

METAPHYSICS.

Definition.

METAPHYSICS has been defined, by a writer deeply versed in the ancient philosophy, "the science of the principles and causes of all things existing." This definition we think extremely proper; and hence it is, that mind or intelligence, and especially the Supreme Intelligence, which is the cause of the universe, and of every thing which it contains, is the principal subject of this science; and hence, too, the science itself has received its name. Aristotle, indeed, who, of all the ancient metaphysicians whose works have come down to us, was unquestionably the greatest, calls this science the First Philosophy, as being not only superior, but also prior in the order of nature, to the whole circle of the arts and sciences. But what is first in nature is not first to man. Nature begins with causes, which produce effects. Man begins with effects, and by them ascends to causes. Thus all human study and investigation proceed of necessity in the reverse of the natural order of things, from sensible to intelligible, from body the effect, to mind, which is both the first and the final cause. Now Physics being the name given by the Stagyrite to the philosophy of body, some of his interpreters, from this necessary course of human studies, called that of mind Metaphysics; implying by that term not only that its subject is more sublime and difficult, but also that the study of it would be most properly and successfully entered upon *after that of physics*. To this name, which, though it has sometimes been treated with ridicule, is abundantly significant, the followers of Aristotle were led by their master, who, to the books in which he pretends to elevate the mind above things corporeal to the contemplation of God and things spiritual, prefixed the Greek words *μετα τα φυσικα*.

Division of the science.

The science of Metaphysics has been divided, according to the objects which it considers, into six principal parts, which are denominated, 1. Ontology; 2. Cosmology; 3. Anthroposophy; 4. Psychology; 5. Pneumatology; and, 6. Metaphysical Theology.

Ontology.

That part of the science which is named Ontology investigates and explains the nature and essence of all beings, as well as the qualities and attributes which essentially pertain to them. Hence it has been said that ontology should proceed in its operations from the most simple ideas; such as do not admit of any other qualities of which they may be compounded. These simple ideas are, those of being, of essence, of substance, of mode, of existence as well with regard to time as place, of a necessary cause of unity; the idea of negation; the difference between a being that is simple or compound, necessary or accidental, finite or infinite; the ideas of essential and abstract properties, such as of the greatness, perfection, and goodness of beings, &c. The business, therefore, of ontology is to make us acquainted with every kind of being in its nature and essential qualities, by which it is distinguished from all other beings. This knowledge being once established on simple principles, just consequences may thence be drawn, and those things proved into which the metaphysician inquires, and which it is the business of his science to prove.

Divisions of the Science.

It is easy to conceive, that even a clear knowledge of beings, and their essential properties, would be still defective and useless to man, if he did not know how to determine and fix his ideas by proper denominations, and consequently to communicate his perceptions to those whom he would instruct, or against whom he is obliged to dispute. To render our ideas intelligible to others, therefore, we must have determinate words or denominations for each being, and the qualities of each being; and ontology teaches us those terms which are so necessary to fix our ideas, and to give them the requisite perspicuity and precision, that when we endeavour to extend the sphere of our knowledge, we may not waste our time in disputes about words.

Cosmology.

Metaphysics having, in as solid a manner as possible, explained and established the principles above mentioned, continues its inquiries into the second part, which is called Cosmology, and examines into the essence of the world and all that it contains; its eternal laws; the nature of matter and of motion; the nature of tangible bodies, their attributes and adjuncts; and all that can be known by reasoning and experience. It is also in cosmology that the metaphysicians of this school examine the Leibnitzian system; that is, whether God, in creating the world, must necessarily have created the best world; and if this world be so in fact. In this manner they pursue the argument, from consequence to consequence, to its last resort, frequently with very little advantage to truth and science.

Anthroposophy.

Anthroposophy, or the knowledge of man, forms the third branch of metaphysics. It is subdivided into two parts. The first, which consists in the knowledge of the exterior parts of the human frame, belongs not to this science, but to anatomy and physiology. The business of the metaphysician is here to ascertain the nature of those powers by which all the motions essential to life are produced; and to discover, if possible, whether they be corporeal or spiritual. This inquiry leads at the same time to psychology.

Psychology.

Psychology consists in the knowledge of the intellectual soul in particular; concerning which the most profound, the most subtile, and most abstract researches have been made that human reason is capable of; and concerning the substance of which, in spite of all these efforts, it is yet extremely difficult to support any positive opinion with conclusive or probable arguments.

Pneumatology.

The fifth part of metaphysics is called Pneumatology. By this term, which has not been long in use, metaphysicians mean the knowledge of all spirits, angels, &c. It is easy to conceive what infinite art is necessary to give an account of that of which nothing positive can ever be known in the present state of human existence. But the metaphysician of this school readily offers to show us what is the idea of a spirit, and the effective existence of a spirit; what are its general qualities and properties; that there

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[1] This treatise was written for and published in the third edition of this work. Though the greater part of it is, notwithstanding the title, devoted to the *Philosophy of the Mind*, it does not adequately appreciate or discuss the doctrines of the Scottish School—that School in which this important branch of Philosophy has been, as we think, most soundly and persuasively taught, and best illustrated. It however presents a collection and collation of opinions so extensive and elaborate as fully to justify its republication. It had the disadvantage, we may observe, of having been at least *partly* written before the publication of even the first volume of Mr Stewart's invaluable *Elements of the Philosophy of the Mind*. Had circumstances permitted the change, we should have separated this subject from *Metaphysics*, confining the article on the latter to that science alone, in as far as any appropriate or definite meaning can now be assigned to its name, and discussing the former, of new, under its proper head. But not being able, consistently with other considerations, to accomplish this, we here reprint the Treatise nearly as it originally appeared. The reader will be the better able to judge of its compass by being informed, that it not only includes a view of the principal speculations respecting the Intellectual Powers, and respecting Body or Matter and its adjuncts, but also discusses some fundamental portions of Moral Philosophy and Natural Religion,—such as Liberty and Necessity, the Immateriality and Immortality of the Soul, and the Existence and Attributes of the Deity.

Divisions of the Science.

are rational spirits, and that these rational spirits have qualities which are founded in the moral attributes of God; for this is in so many words what is attempted to be taught in pneumatology.

Metaphysical theology.

Metaphysical Theology, which Leibnitz and some others call Theodicy, is the sixth and last branch of the science of metaphysics. It teaches us the knowledge of the existence of God; to make the most rational suppositions concerning his divine essence; to form a just idea of his attributes and perfections, and to demonstrate them by abstract reasoning. Theodicy differs from natural theology, inasmuch as this last borrows, in fact, from theodicy, proofs and demonstrations to confirm the existence of a Supreme Being; but after having solidly established that great truth, natural theology, by extending its consequences, teaches us what are the relations and connexions which subsist between the Supreme Being and men, and what are the duties which result from these relations.

This division useless and improper.

We have briefly mentioned these divisions of the science, because they were once prevalent in the schools. The greater part of them, however, appears to us to be not only superfluous, but such as can serve no other purpose than to perplex the mind. The only beings of which we know any thing are mind and body; and we have no reason to think that there are any other beings in the universe. Of bodies indeed there are various kinds, endowed with different properties; and it is also extremely probable, that, of minds endowed with different powers, the variety may be equally great. Our own minds we know to be united in one system with bodies by which they perform all their operations; and we can demonstrate that there is another mind, which is independent of all body, and is the cause of all things. Between these there may be numberless orders of minds; but their energies are wholly unknown to us, and therefore they can never become the objects of science.

Mind and body, therefore, that is, the minds and bodies which we know to exist, together with their powers and properties, essential and accidental, can alone be the subjects of rational inquiry. We may inquire into the essence of mind and the essence of body, and endeavour to ascertain in what respects they differ; we may examine the nature of different bodies, in order to discover whether all bodies, however modified, have not something in common; and we may consider the properties, relations, and adjuncts of bodies, and endeavour to distinguish those which are accidental from such as appear to be so necessary that without them body itself could not exist. But of minds we cannot make the same comparison. In this part of the science we have not sufficient data for an accurate and complete induction. We can only examine the powers of our own mind, and by probable analogy make some estimate of the powers of superior minds, as observation will help us to guess at the powers of those which are placed beneath us in the scale of existence.

If this be so, cosmology, as distinguished from ontology, cannot properly be a branch of metaphysics; for if mind and body, with their several powers, properties, and adjuncts, compose the universe, it is obvious, that when we have ascertained, as well as we are able, the essence of mind and the essence of body, together with the powers and properties of each, and have traced them all to the first cause, we have done every thing in the science of the universe, if we may use the expression, which belongs to the province of the metaphysician. The particular laws of motion on the earth and in the planetary system belong to the natural philosopher and the astronomer.

In like manner, anthroposophy, psychology, or pneumatology, if these be not words expressive of distinctions where there is no difference, appear to be at least very needlessly disjoined from one another. Of the nature of spirits we can know nothing but from contemplating the powers of our own minds; and the body of man is in the province, not of the metaphysician, but of the anatomist and physiologist. Anthroposophy, psychology, and pneumatology, if they be used to denote our knowledge of all minds except the Supreme, are words of the same import; for of no created minds except our own can we acquire such knowledge as deserves the name of science.

Divisions of the Science.

Ontology has sometimes been defined the science of *being in the abstract;* but in the course of our inquiries it will be seen, that *being in the abstract* is a phrase without meaning. Considered as the science of real beings and their properties, ontology is a very significant word, of the same import with metaphysics, and comprehending in itself the knowledge of the nature of all things existing. Or if it be thought proper to make a distinction between ontology and theology, the former branch of the science will teach the knowledge of body and created minds, whilst it is the province of the latter to demonstrate the existence and attributes of that mind which is uncreated.

Another division proposed.

Body and mind, therefore, with their properties, adjuncts, and powers, comprehend the whole subject of the science of metaphysics; and as we are more early acquainted with body than with mind, the natural order of conducting our inquiries seems to be, to begin with the former, and thence proceed to the latter. It is obvious, however, that if we would pursue these inquiries with any hopes of success, we must first trace human knowledge from its source; ascertain the nature of truth; and show what kind of evidence on each topic to be treated ought to enforce conviction. In this view of the science, metaphysics appears to be divided into three parts; the first treating of Human Understanding; the second of Body, with its adjuncts; and the third of Mind, with its powers.

Idea and notion explained.

Previously to entering upon such inquiries, some philosophers of great merit have thought it expedient to explain the terms which they might have occasion to use. Their conduct is judicious, and worthy of imitation; for the objects of metaphysics being, for the most part, such as do not fall under the cognizance of the senses, are liable to be differently apprehended by different men, if the meanings of the words by which they are expressed be not ascertained with the utmost precision. We intend, however, to use very few words except in the common acceptation; and we therefore hope, that as terms of science are explained under different words in the dictionary, to which references are made, we shall have little or no occasion for swelling the article by previous definitions. There are indeed two words which have given rise to much useless disputation, which yet cannot be banished from speculative philosophy, and which it will therefore be proper here to define. The words to which we allude are *idea* and *notion*. These are very generally considered as synonymous; but we think that much logomachy might have been avoided by assigning to each a determinate signification. We know not any philosopher who made much use of the word *idea* before Plato; but with his mysterious doctrine concerning ideas we have here nothing to do. Our present business is to ascertain the precise meaning of the word, which is evidently derived from *εἰδω, to see*, as the word *notion* is from "nosco, novi, *notum*," and that from *γινωσκω, to know* or *understand*.[1] In the original sense of the two words, therefore, *notion* is more comprehensive than *idea*, because we *know* many things which cannot be

[1] The metaphysical student will do well to peruse the learned observations on the history and fortune of the word *Idea*, contained in an article on the *Philosophy of Perception*, in the fifty-second volume of the *Edinburgh Review*, page 182.—*Note to the present Edition.*

Origin of Ideas.

seen. We have not a doubt but that at first the word *idea* was employed to denote only those forms of external objects which men contemplate in their imaginations, and which are originally received through the sense of sight. Its signification was afterwards extended to the relicts of every sensation, of touch, taste, sound, and smell, as well as of sight; and at last it was confounded with *notion*, which denotes the mental apprehension of whatever may be known. In our use of the word *idea*, except when we quote from others, we shall employ it only to denote that appearance which absent objects of sense make in the memory or imagination; and by the word *notion* we shall denote our apprehension or knowledge of spirits, and all such things as, though they be the objects of science, cannot be perceived by the external senses. Having said this, we proceed to our inquiries, beginning with that into human understanding.

PART I.

OF HUMAN UNDERSTANDING.

Preliminary Observations on the Origin of our Ideas and Notions.

No innate ideas in the human mind.

That the mind of man has no innate ideas or notions, but comes into the world ignorant of every thing, is a truth which, since the days of Locke, has been very little disputed. In the first book of his Essay on Human Understanding, that very acute philosopher has demonstrated, that the rudiments or first principles of all our knowledge are communicated to us by sensation; and he has compared the mind, previously to the operation of external objects upon the senses, to a *tabula rasa*, or sheet of white paper. To repeat his arguments would swell this article to no purpose. There is not a man capable of attending to his own ideas, who can entertain a doubt in what manner he received them. Without the sense of sight, we could never have known colours; nor sound, without hearing; nor hardness, softness, smoothness, bodily pain or pleasure, without touch; nor odours, without smell, &c.

Self-evident as these facts are, objections have been started to the inferences drawn from them; and Locke has been accused of advancing principles subversive of all distinction between truth and falsehood, and favourable of course to universal scepticism. "The first book of his Essay, which, with submission," says Dr Beattie,[1] "I think the worst, tends to establish this dangerous doctrine, that the human mind, previous to education and habit, is as susceptible of one impression as of another; a doctrine which, if true, would go near to prove that truth and virtue are no better than human contrivances; or at least that they have nothing permanent in their nature, but may be as changeable as the inclinations and capacities of men; and that there is no such thing as common sense in the world. Surely this is not the doctrine which Mr Locke meant to establish." We are so thoroughly satisfied that it is not, that we cannot help wondering how such inferences could, by a man of learning, genius, and candour, be drawn from any thing which is to be found in the Essay on Human Understanding.

But the doctor thinks Mr Locke's "simile of the mind to white paper one of the most unlucky allusions that could have been chosen; because the human soul, when it begins to think, is not extended, nor of a white colour, nor incapable of energy, nor wholly unfurnished with ideas, nor as susceptible of one impression or character as of any other." And it has been observed by another objector,[2] that "on a sheet of white paper you may write that sugar is bitter, wormwood sweet, fire and frost in every degree pleasing and sufferable; that compassion and gratitude are base; treachery, falsehood, and envy, noble; and that contempt is indifferent to us."

Origin of Ideas.

Objections answered.

All this is true, but we apprehend it is not to the purpose. Mr Locke has nowhere expressed himself in such a manner as to lead us to suppose that he believed the soul to be extended or coloured, or, when it begins to think, incapable of energy, and wholly unfurnished with ideas; but he certainly did believe that it does not begin to think at the first instant of its existence, and that it acquires all the ideas of which it is ever possessed. We may undoubtedly write upon a piece of white paper that sugar is bitter, and that wormwood is sweet; but how the capacity of paper to receive the symbols of false propositions should make Mr Locke's comparison improper or dangerous, we cannot comprehend. Mr Usher indeed says, that it is improper on this account, "that no human art or industry is able to make those impressions upon the mind; in respect of them, the mind discovers not a passive capacity, but resists them with the force of fate." Does it indeed? Does the mind reject the idea of sugar or of bitterness, of contempt or of indifference? May not any man have the idea of sugar, and at the same time the idea of bitterness, and compare the one with the other in his mind, as well as the word sugar may be written beside the word bitter, and connected with it on the same piece of paper? In all this we perceive nothing that is impossible, nor even difficult. The mind cannot indeed be made to feel that sugar has the same taste with wormwood; but who ever thought that it could? Not Mr Locke, we shall be bold to say; nor does his simile give the smallest countenance to such an absurdity. The great author of the Essay on Human Understanding understood his subject too well to imagine that either truth or falsehood could be communicated to paper, or that paper is capable of comparing ideas. Paper is capable of receiving nothing but lines or figures, and it passively receives whatever lines or figures we may choose to inscribe upon it; yet if a pen be carried over it in a circular direction, the figure impressed will not be a square; just as, to the mind of one eating sugar, the taste communicated is not that of wormwood.

On a piece of paper a circle may be described, and close beside it a square; in like manner an agreeable sensation may be communicated to the mind, and immediately afterwards a sensation that is disagreeable. These two sensations, or the ideas which they leave behind them, may be compared together; and it is certainly true that no art or industry can make them appear similar in the mind. But is it not equally true that no art or industry can make the circle and the square similar on the paper? The paper is susceptible of any sort of plain figures, and the mind is equally susceptible of any sort of ideas or sensations; but figures dissimilar cannot be made to coincide, neither can discordant ideas be made to agree. Again, one may write upon paper that a circle *is* a square, and likewise that a circle *is not* a square; and both these propositions may be communicated to the mind by the organs of sight or of hearing. The paper receives the words expressive of the false as well as those expressive of the true proposition; and the mind receives the ideas and relations signified by the one cluster of words as well as those signified by the other; but in the mind the idea of a square is very different

[1] Essay on the Nature and Immutability of Truth.

[2] Usher, author of *Clio*. See a volume of Fugitive Pieces, printed for J. Davies, London, 1774.

Origin of Ideas.

from that of a circle, and on the paper the figure of a square is very different from the figure of a circle. The great difference between the mind and the paper is, that the former is conscious of its ideas, and perceives their agreement or disagreement; whereas the paper is *not* conscious of the figures drawn upon it, nor perceives any thing about them. But still these figures are what they are; they either agree or disagree on the paper, as well as the ideas either agree or disagree in the mind. It is not in the power of the mind to alter the ideas of the square and the circle, nor in the power of the paper to alter the forms of these figures.

It appears, then, that the principles of Mr Locke, and the comparison by which he illustrates them, have no more tendency to subvert the difference between truth and falsehood, right and wrong, than the passiveness of paper has to subvert the difference between a straight line and a crooked, a circle and a square; and with a view to establish the doctrine of innate ideas and instinctive principles of knowledge, we might with as much propriety ask, whether it be possible to imagine that any mode of manufacture could make paper of such a nature as that a pen drawn over it in a circular direction would leave the figure of a square, as, whether it be possible to imagine that any course of education could ever bring a rational creature to believe that two and two are equal to three.

All derived from sensation and reflection.

The mind being thus, as we may say, originally white paper, void of all characters, without ideas or notions of any kind, the first question which we have to consider is, whence and in what manner it derives the materials of all its knowledge? To this question the only answer which can be given is, that it derives them from observation and experience; from observation, either employed upon external objects of sense, or turned inwardly upon its own operations. Our senses, conversant about particular external objects, convey into the mind several distinct perceptions; such as those of colour, figure, heat, cold, bitterness, sweetness, and all those things which are usually called sensible qualities. The notions, ideas, or whatever else they may be called, which are acquired in this manner, may be called sensible knowledge; and the source of that knowledge is termed sensation.

The other fountain from which experience furnishes the understanding with knowledge, is that attention which we are capable of giving to the operations of our own minds when employed about those ideas which were originally suggested by objects of sense. These operations, when the soul comes to reflect on them, furnish us with a set of notions entirely different from the ideas of sense; such as the notions of perception, thinking, doubting, believing, reasoning, knowing, willing, and all the different energies and passions of our own minds. Of these operations we are always conscious when we are awake; but it requires, as shall be shown afterwards, no inconsiderable effort to set them, as it were, at a distance, to reflect on them, and consider what they are. When we have made this effort, however, we acquire notions as distinct, and perhaps more important, than those ideas which we receive through the medium of the senses.

Sensation and reflection, then, furnish mankind with the first materials of all their knowledge. The mind seems not to have ideas or notions of any kind which it did not receive by one or other of these modes. By means of the senses it perceives external objects; and by that power which it has of turning its attention upon itself, it discovers the nature and manner of its own operations.

Although the knowledge which we acquire from reflection be of equal importance, and perhaps of greater certainty than that which we receive through the medium of the senses, it comes into the mind at a much later period; both because it is impossible that the faculties of the mind should operate without materials, and because it is much more difficult to attend to these operations, even whilst they are going on, than to the objects of sense which solicit our attention. It is for this reason pretty late before children have any notions whatever of the operations of their own minds; and of the greater part of these operations the bulk of mankind have no clear or accurate notions during the whole of their lives. On the other hand, every human being is so surrounded with bodies, which perpetually and variously affect his senses, that a variety of sensible ideas force an entrance even into the minds of children. In order therefore to trace the procedure of the understanding, and to ascertain the extent and limits of human knowledge, it should seem that we must begin with considering the external senses, that we may discover the manner in which we receive knowledge by means of them, the objects of that knowledge, and its certainty. It is to be observed, however, that though we consider the mind as possessed of many powers or faculties, and inquire first into the nature of that faculty which we conceive to be first exerted, this is done merely for the sake of proceeding in our subject with method and perspicuity. The mind is one simple and undivided being; and in every mental energy it is the whole mind, and not any part or portion of it, that is energetic. On this account it is impossible to explain even the nature of sensation and perception to him who knows not what is meant by will or understanding; but to every one who is acquainted with the common import of these words, and who has read the treatise on Logic inserted in this work, we hope that our theory of perception will be intelligible and convincing.

Of Sensation.

CHAP. I.—OF SENSATION AND PERCEPTION.

Sect. I.—*Of Sensation.*

Sensation by five organs.

The Supreme Being, who made us and placed us in this world, has given us such powers of mind as he saw to be suited to our state and rank in his creation. He has given us the power of perceiving many objects around us; but that power is limited in various ways, and particularly in this, that without the organs of the several senses we perceive no external object. The senses, as every one knows, are five in number, and each communicates its proper sensation. It is by the eyes alone that we see, by the ears that we hear, by the nose that we smell, and by the tongue and palate that we taste; the sense of feeling or touch is spread over the whole body, for we feel equally by our hands and by our feet, &c. To the powers of perception by the senses it is necessary not only that we have all the organs enumerated, but that we have them also in a sound and natural state. There are many disorders of the eye which cause total blindness, as well as others which impair without destroying the power of vision. The same thing is true of the organs of all the other senses.

These organs themselves not sentient.

All this is so well known from experience, that it needs no proof; but it may be worth while to observe, that it is known from experience only.[1] For any thing that we know to the contrary, our Creator might have endowed us with the power of perception by a thousand organs of sense, all different from those which we possess; and it is certain that he himself perceives every thing more perfectly than we do without bodily organs. For it is to be observed, that the organs of sense are different from the being which is sentient. It is not the eye which sees, nor

[1] Reid's Essays on the Intellectual Powers of Man.

Of Sensation.

the ear which hears; these are only the organs by which we see and hear. A man cannot see the satellites of Jupiter except by means of a telescope, nor hear a low voice except by means of an ear-trumpet. Does he from this conclude that it is the telescope which sees those satellites, or the trumpet which hears that voice? Such a conclusion would be evidently absurd. It is no less absurd to conclude that it is the eye which sees, or the ear which hears. The telescope and the trumpet are artificial organs of sight and of hearing, of which the eye and ear are natural organs; but the natural organs see and hear as little as the artificial.

Instruments of sensation.

That this is the case with respect to the eye and the ear, is so obvious, that, as far as we know, it has never been denied. But with respect to the senses of touch, taste, and smell, the truth at first view does not appear so evident. A celebrated writer has observed,[1] that "after the utmost efforts, we find it beyond our power to conceive the flavour of a rose to exist in the mind; we are necessarily led to conceive that pleasure as existing in the nostrils, along with the impression made by the rose upon that organ;[2] and the same will be the result of experiments with respect to every feeling of taste, touch, and smell. Touch," he says, "affords the most satisfactory evidence, and philosophy detects the delusion." To detect this delusion requires, indeed, no great depth in philosophy; for it is so far from being true that we are necessarily led otherwise than by association, of which the laws shall afterwards be explained, to conceive the pleasure or pain of touch as existing at that part of our body upon which the impression is made, that, as every man must have observed, children, previously to experience, cannot distinguish the precise place of their bodies which is affected by the touch of any external object. Nay, we believe it will be found upon trial, that if a full-grown man, with all the experience of age to guide him, be pricked with a pin on any part of his body which he has seldom handled, and never seen, he will not readily, nor at first, put his finger upon the wound, nor even come very *near* to the wound. This, however, he would certainly and infallibly do were the sense of touch necessarily conceived as existing in the organ. To these observations objections may perhaps be made, which we cannot stay to obviate; but the following, we think, will admit of none. We appeal to every man who has experienced that particular sensation of touch which Scaliger has dignified with the name of a sixth sense, whether, whilst those sensations were new to him, he was necessarily led to conceive them as existing in any particular organ. If he was not, it then follows undeniably that the organs of sensation are different from the being which is sentient; that it is not the eye which sees, the ear which hears, the nostrils which smell, the tongue which tastes, nor any part of the body which feels; and that it is by experience alone that we learn to associate our several sensations with those organs upon which the impressions are made.

The brain and nerves necessary to sensation.

It is, however, certain that we receive no sensation from external objects, unless when some impression is made upon the organ of sense, either by the immediate application of the object itself, or by some medium which passes between the object and the organ.[3] In two of our senses, viz. touch and taste, there must be an immediate application of the object to the organ. In the other three the sensation is occasioned by the impression of some medium passing from the object to the organ. The effluvia of bodies drawn into the nostrils with the breath are the medium of smell; the undulations of the air are the medium of hearing; and the rays of light passing from visible objects to the eye are the medium of sight. These are facts known from experience to hold universally both in men and in brutes. It is likewise a law of our nature perfectly known to all who know any thing of anatomy, that, in order to actual sensation, the impressions made upon the external organs must be communicated to the nerves, and from them to the brain. First, the object, either immediately, or by some medium, makes an impression upon the organ; the organ serves as a medium by which the impression is communicated to the nerves; and the nerves serve as a medium to carry it on to the brain. Here the corporeal part ends; at least we can trace it no farther. The rest of the process is purely intellectual. The proof of these impressions upon the nerves and brain in sensation is this, That from many observations and experiments it is found, that when the organ of any sense is perfectly sound, and has the impression made upon it by the object ever so strongly, yet if the nerve which serves that organ be cut or tied hard, there is no sensation; and it is well known that disorders in the brain deprive us of sensation, whilst both the organ and its nerve remain sound.

Process of nature in sensation.

There is sufficient reason, therefore, to conclude, that in sensation the object produces some change in the organ; that from the organ the change proceeds to the nerve, and from the nerve to the brain. Hence it is that we have positive sensations from negative objects or mere nonentities, such as darkness, blackness, and vacuity. For, sensation resulting from changes in the brain, whatever produces any change must of course occasion a new sensation; but it is obvious that the mere absence of any impression, by the removal of the object which produced it, must as necessarily cause a change in the organ, nerves, and brain, as the presence of a new impression from a new object. To these changes, or that which immediately produces them, we give the name of impressions; because we know not how, in a general manner, to express more properly any change produced by an external cause, without specifying the nature of that cause. Whether it be pressure, or attraction, or repulsion, or vibration, or something unknown, for which we have no name, still it may be called an impression.

The mind partly active in sensation.

Sir Isaac Newton was perhaps the first who supposed that the rays of light falling upon the bottom of the eye excite vibrations in the *tunica retina;* and that these vibrations, being propagated along the solid fibres of the optic nerves into the brain, cause the actual sensation of seeing. This hypothesis was adopted by Dr Hartley, applied to the other senses, and shown to be at least as probable as any which has yet been invented to account for the perception of external objects by means of the organs of sense. Be this as it may, experience informs us, that whatever be the nature of those impressions and changes which are made by external objects upon the senses, nerves, and brain, we have without them no actual sensation, and of course perceive

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[1] Kames's Elements of Criticism.

[2] Another eminent writer thinks very differently on this subject, and in our opinion much more justly. "Suppose," says Dr Reid, "a person who never had this sense (*smell*) before, to receive it all at once, and to smell a rose; can he perceive any similitude or agreement between the smell and the rose, or indeed between it and any other object whatever? Certainly he cannot. He finds himself affected in a new way, he knows not why, or from what cause. He is conscious that he is not the cause of it himself; but he cannot, from the nature of the thing, determine whether it be caused by body or spirit, by something near or by something at a distance. He cannot give it a *place*, any more than he can give a place to melancholy or joy; nor can he conceive it to have any existence but when it is smelled." (*Inquiry into the Human Mind*, ch. ii. sect. ii.)

[3] Reid's Essays on the Intellectual Powers of Man, and Hartley's Observations on Man.

Of Perception.

nothing *ab extra*. Hence it has been supposed that the mind is wholly passive in sensation, and that sensation is necessarily produced by those impressions. But this we believe to be a mistake. Every man who has been attentive to his own thoughts and actions, must know instances of impressions having been certainly made upon his organs of sense without producing any sensation, or suggesting to his mind the perception of the particular objects by which the impressions were caused. He whose mind is intensely employed in any particular pursuit may have his eyes open upon an object which he does not see, or he may not hear the sound of a clock striking within two yards of him; nay, we will venture to affirm, that there is hardly one reader of this article to whom such absences of sensation have not often occurred. Now, as there is no reason to suppose, that in the one case the undulations of the air caused by the striking of the clock did not reach his ears, or that in the other the rays of light reflected from the object did not fall upon his eyes, which were open to receive them, the only reason which can be assigned for his not having, in these instances, had audible and visible sensations, is, that his mind was so engaged in something else as not to pay to the vibrations in his brain that attention, if we may so express it, without which impressions *ab extra* can produce no sensation. There are, indeed, some impressions on the organs of sense so violent and so sudden as to force themselves upon the mind, however employed. Such are those made on the ear by thunder, and on the eye by strong light. In these cases, sensation is involuntary and unavoidable; whence we conclude, not that in such instances the mind is passive or destitute of energy, but that, by the violent agitation given to the brain, it is roused from its reverie, and compelled to give attention. It appears, therefore, that in sensation the mind exerts some kind of energy; for in nothing but in the sentient being itself can we seek for the cause why, when all external circumstances are the same, organical impressions sometimes produce sensations and sometimes not; and that cause can only be the energy of the mind, though of what kind that energy is we pretend not to say.

Sect. II.—*Of Perception by the Senses.*

Difficult to account for perception.

How the correspondence is carried on between the thinking principle within us and the material world without us, has always, as Dr Reid observes, been found a very difficult problem to those philosophers who consider themselves as obliged to account for every phenomenon in nature. It is, indeed, a problem of which we do not expect ever to see a complete solution. A few steps beyond the vulgar we may certainly go; but the nature of that connection by which the mind and body are united will probably remain for ever unknown. One question, however, which has employed much of the attention of philosophers, both ancient and modern, appears to be not wholly unanswerable. It is, whether, by means of our senses, we perceive external objects mediately or immediately; or, in other words, whether sensation and perception be one and the same thing, or two things succeeding each other? On this subject, till of late, there appears to have been in the main a great uniformity in the sentiments of philosophers, notwithstanding their variations respecting particular points. Of some of the most eminent of them we shall give the opinions, as we find them collected by one[1] who was well acquainted with their writings, who was thoroughly qualified to estimate their respective merits, and who cannot be suspected of partiality to that theory which we feel ourselves compelled to adopt.

Of Perception. Plato.

"Plato illustrates our manner of perceiving external objects thus: He supposes a dark subterraneous cave, in which men lie bound in such a manner as that they can direct their eyes only to one part of the cave. Far behind there is a light, of which some rays come over a wall to that part of the cave which is before the eyes of our prisoners. A number of men variously employed pass between them and the light, whose shadows are seen by the prisoners, but not their persons themselves. In this manner did that philosopher conceive that by our senses we perceive not things themselves, but only the shadows of things; and he seems to have borrowed his notions on this subject from the disciples of Pythagoras.

Aristotle.

"If we make due allowance for Plato's allegorical genius, his sentiments with respect to sensation and perception correspond very well with those of the Peripatetics. Aristotle, the founder of that school, seems to have thought that the soul consists of two or three parts; or rather that we have three souls, the vegetable, the animal, and the rational. The animal soul is held to be a certain form of the body, which is inseparable from it, and perishes at death. To this soul the senses belong; and he defines a sense to be that which is capable of receiving the sensible forms, or species of objects, without any of the matter of them; as wax receives the form of the seal without any of its matter. Of this doctrine it seems to be a necessary consequence, that bodies are constantly sending forth, in all directions, as many different kinds of forms without matter as they have different sensible qualities. This was accordingly maintained by the followers of Aristotle, though not, as far as we know, taught by himself. They disputed concerning the nature of these forms or species, whether they were real beings or nonentities; but of matter and form we shall have occasion to speak afterwards.

Descartes.

"After Aristotle had kept possession of the schools for more than a thousand years, his authority, which had often supplied the place of argument, was called in question by Lord Bacon and others. Descartes, however, was the first philosopher who, convinced of the defects of the prevailing system, attempted to form another entirely new; but on the nature of perception by means of the senses he differs little or nothing from those who had preceded him in that department of science. He denies, indeed, and refutes by solid reasoning, the doctrine which maintains that images, species, or forms of external objects, come from the objects themselves, and enter into the mind by the avenues of the senses. But he takes it for granted, as all the old philosophers had done, that what we immediately perceive must be either in the mind itself, or in the brain, in which the mind is immediately present. The impressions made upon our organs, nerves, and brain, can be nothing, according to his philosophy, but various modifications of extension, figure, and motion. There can be nothing in the brain like sound or colour, taste or smell, heat or cold. They are sensations in the mind, which, by the laws of the union of the soul and body, are raised on occasion of certain traces in the brain; and although he sometimes gives the name of ideas to these traces, he does not think it necessary that they should be perfectly like the things which they represent, any more than that words and signs should resemble the things which they signify.

"According to this system, it would appear that we perceive not external objects directly by means of our senses; but that these objects, operating either mediately or immediately upon the organs of sense, and they again upon our nerves and brain, excite in the mind certain sensations; whence we infer the existence of external objects from our sensations, of which they are the cause. Percep-

[1] Dr Reid in his Essays on the Intellectual Powers of Man.

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tion of external objects, therefore, according to Descartes, is not one simple original act of the mind, but may be resolved into a process of reasoning from effects to causes."

Malebranche.

The doctrines of Malebranche, Locke, and Hartley, respecting perception, differ not essentially from that of Descartes. Malebranche, indeed, supposes that external objects are not themselves the causes of perceptions; but that the Deity, being always present to our minds more intimately than any other being, does, upon occasion of the impressions made upon our organs of sense, discover to us, as far as he thinks proper, and according to fixed laws, his own ideas of the object; and thus, according to him, we see all things in God, or in the divine ideas. He agrees, however, with Descartes and the ancient philosophers, in considering it as a truth which it is impossible to refute, that we perceive not the objects without us, the sun, moon, and stars, &c., because it is not likely that the soul sallies out of the body, and takes a walk, as it were, through the heavens to contemplate these objects. She sees them not therefore by themselves; and the immediate object of the mind, when it sees the sun, is not the sun itself, but something which is intimately united to the mind, and is that which he calls an *idea*.

Locke.

Locke, speaking of the reality of our knowledge, says: "It is evident the mind knows not things immediately, but only by the intervention of the ideas it has of them. Our knowledge, therefore, according to him, is real only so far as there is a conformity between our ideas and the things which they represent." And the manner of our perceiving external objects he illustrates by the following similitude: "Methinks the understanding is not much unlike a closet wholly shut from light, with only some little opening left, to let in external visible resemblances, or ideas of things without. Would the pictures coming into such a dark room but stay there, and lie so orderly as to be found upon occasion, it would very much resemble the understanding of a man in reference to all objects of sight, and the ideas of them."[1] He has elsewhere[2] defined an idea thus: "Whatsoever the mind perceives in itself, or is the immediate object of perception, thought, or understanding, that I call an *idea*; and the power to produce any idea in our mind I call *quality* of the subject wherein the power is." He likewise thinks it easy to draw this observation, that the ideas of what he calls primary qualities of bodies, viz. extension, solidity, figure, mobility, &c. are resemblances of these qualities as they really exist in the bodies themselves.

This unguarded expression, which affirms that ideas in the mind are the resemblances of external things, has brought upon Mr Locke much undeserved ridicule. That upon this and other occasions he uses the word idea with too great latitude, and that he often confounds ideas with sensations, and even with the causes of sensation, must be admitted by his warmest admirers; but we believe that by an attentive reader, who peruses his whole work, and compares such passages as are obscure with those which are clearer, his meaning may always be discovered, and, with respect to sensation and perception, will generally be found just. That by calling the ideas of primary qualities resemblances of the qualities themselves, he meant nothing more than that bodies in all possible states impress the senses, nerves, and brain, in such a manner as to produce in the mind certain sensations, between which and those impressions there is an inseparable though unknown connection, is evident from the account which he gives of the manner of perception. "Our senses," says he, "conversant about particular sensible objects, do convey into the mind several distinct perceptions of things, according to those various ways in which these objects affect them; and thus we come by those ideas we have of yellow, white, heat, cold, soft, hard, bitter, sweet, and all those which we call sensible qualities; which, when I say the senses convey into the mind, I mean they, from external objects, convey into the mind what produces those perceptions." And as bodies can act only by impulse, he adds, that "those perceptions can be produced only by an impression made upon the senses, and some motion thence continued by our nerves to the brain or seat of perception."

Of Perception.

Hartley.

Dr Hartley was the pupil of Locke and Newton; and, in a more satisfactory manner than all who had preceded or have since followed him, explained the material part of the process of perception. His principles we shall have occasion, during the course of this article, to develope pretty fully. For our present purpose it is sufficient to say, that all his observations and arguments evidently suppose, that nothing distant from the mind can be perceived in the immediate act of sensation; but that the apparently immediate perception of external objects is an instance of early and deep-rooted association.

Hume.

In this sentiment Mr Hume agrees with his predecessors; but he obscures his philosophy, and misleads his reader, by confounding sensations with the impressions from which they proceed. "Every one," says he,[3] "will allow that there is a considerable difference between the perceptions of the mind when a man feels the pain of excessive heat, or the pleasure of moderate warmth, and when he afterwards recalls to his memory this sensation, or anticipates it by his imagination." The less forcible and lively of these perceptions he with great propriety calls *ideas*; but it is either through wilful perverseness, or confusion of intellect, that he chooses to call the others *impressions*. Sensation and perception are caused by *impressions*; but they are no more impressions themselves than the pain occasioned by the stroke of a bludgeon is the stroke itself, or the bludgeon with which it was struck. But more of this afterwards.

Agreement of philosophers, and the reason of it.

Thus far, then, that we perceive not external objects directly, but infer their existence from certain sensations excited in our minds by the operation of these objects upon our senses, nerves, and brain, seems to have been the opinion of almost every philosopher from Pythagoras[4] to Mr Hume. For an opinion so universal, and at the same time so contrary to the persuasion of the multitude, some cogent reason must have been assigned. That reason has been given by many philosophers, but by none with greater perspicuity than Dr Porterfield, in his Essay concerning the Motion of the Eyes. "How body acts upon the mind, or mind upon body," says he, "I know not; but this I am very certain of, that nothing can act, or be acted upon, where it is not; and therefore our mind can never perceive any thing but its own proper modifications, and the various states of the sensorium to which it is present. So that it is not the external sun and moon, which are in the heavens, that our mind perceives, but only their image or representation impressed on the sensorium. How the soul of a seeing man sees those images, or how it receives those ideas from such agitations in the sensorium, I know not; but I am sure it can never perceive the external bodies themselves, to which it is not present."

This reasoning appears to have force, and perhaps the

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[1] Essay on Understanding, book ii. chap. xi.
[2] Book ii. chap. viii.
[3] Inquiry concerning Human Understanding, sect. iii.
[4] See Mosheim's edition of Cudworth's Intellectual System, where the opinions of the philosophers of antiquity are more faithfully collected than in any other work with which we are acquainted.

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unanimous agreement of thinking men in all ages has still greater force; yet the doctrine which prevailed so long, and which to Locke appeared so evident as to need no proof, has since been called in question by some eminent philosophers in our own country, who, though they allow that we cannot perceive external objects except by means of the senses, yet affirm that they are the objects themselves which we perceive directly, and that in perception there is no association which can be resolved into a process of reasoning from sensations the effects, to external objects the causes. Dr Reid, who was perhaps the first of this class of philosophers, had expressed himself distinctly on this subject.

"If we attend to the act of our mind which we call the perception of an external object of sense, we shall find it in these three things: *First*, some conception or notion of the object perceived; *secondly*, a strong and irresistible conviction and belief of its present existence; and, *thirdly*, that this conviction and belief are immediate, and not the effect of reasoning."[1] To the first and second of these propositions we are persuaded that Descartes and Locke would readily have assented; nor do we imagine that they would have denied the third, had the author allowed that this strong and irresistible conviction is the consequence of an early and deep-rooted association, resolvable into a process of reasoning. This, however, the learned professor does not allow, for he repeatedly affirms that it is instinctive and original, and that "the constitution of our power of perception determines us to hold the existence of what we distinctly perceive as a first principle, from which other truths may be deduced, but it is deduced from none." With this view of the matter, he could with no propriety attempt to support his own opinion by argument; but to the reasonings of Dr Porterfield and others in defence of the Cartesian theory, he replies in the following words: "That nothing can act immediately where it is not, I think must be admitted; for I agree with Sir Isaac Newton, that power without substance is inconceivable. It is a consequence of this, that nothing can be acted upon immediately where the agent is not present; let this, therefore, be granted. To make the reasoning conclusive, it is farther necessary, that when we perceive objects, either they act upon us, or we act upon them. This does not appear self-evident, nor have I ever met with any proof of it."[2]

Of the profundity of Dr Reid's understanding we have the most firm conviction; nor is there any metaphysician, ancient or modern, from whom we differ with greater reluctance; but we cannot help thinking this a rash assertion, as his own works appear to us to afford complete proof that, in perception, the mind both acts and is acted upon. Let us attend, however, to the reasons which, on this occasion, induced him to think that in perception there is no action either of the object on the mind or of the mind on the object.

"When we say that one being acts upon another, we mean that some power or force is exerted by the agent which produces, or has a tendency to produce, a change in the thing acted upon. If this be the meaning of the phrase, as I conceive it is, there appears no reason for asserting that, in perception, either the object acts upon the mind or the mind upon the object. An object, in being perceived, does not act at all. I perceive the walls of the room where I sit; but they are perfectly inactive, and therefore act not upon the mind. To be perceived, is what logicians call an external denomination, which implies neither action nor quality in the object perceived."

This last sentence we do not pretend to understand. Substance without qualities is to us inconceivable, and certainly is no object of perception; for Dr Reid himself has told us, and told us truly, that "the objects of perception are the various qualities of bodies." That an object, in being perceived, does not act at all, is directly contrary to what the ingenious author has taught us, both in his Inquiry and in his Essays, viz. that "it is a law of our nature that we perceive not external objects, unless certain impressions be made by the object upon the organ, and, by means of the organ, upon the nerve and brain;" for if the external object, in being perceived, make impressions, it is certainly not true that it does not act at all. It is indeed readily acknowledged, that when one perceives the walls of the room where he sits, these walls do not act immediately upon the organs of sight; but it does not therefore follow that they are perfectly inactive; for it is known to all mankind, that from every point of the wall which is seen, rays of light are reflected to the eye; that these rays make upon the *retina tunica* an impression, which is conveyed by the optic nerve to the brain; and that this impression on the brain is one of the immediate causes of vision. In what particular manner it causes vision, we shall never be able to discover, till we know more of the laws which unite mind and body, and by which one of these is qualified to act upon the other; but, because we know not the manner of this operation, to affirm that there is no operation at all, seems to be as absurd as it would be to affirm, because we perceive no necessary connection between a stroke and the sensation of sound, that the sound of a musical string is not caused by the stroke of a plectrum. That God might have given us powers of perception of a different kind from those which we possess, there can be no doubt; but with what we might have been we have no concern. As we are, we know perfectly that the eye is an instrument of vision, because without it nothing can be seen; we know also that the retina and optic nerves are equally necessary, because, if they be disordered, vision is still wanting; we know likewise that the brain is necessary to all perception, because, when it is disordered, thinking either entirely ceases or is proportionably disturbed. And, lastly, we are not more certain of our own existence, than that actual perception does not take place except when the object makes an impression upon some organ of sense; for when no rays of light fall upon the eye, we see nothing; when no sapid body is applied to the tongue and palate, we taste nothing; and if we could be removed from every thing solid, we should feel nothing.

These are conclusions which cannot be controverted. They are admitted equally by the philosopher and by the plain unlettered man of common sense; nor are they rendered one whit less certain by our not being able to go a step farther, so as to discover in what manner the brain or the affections of it can be the immediate instrument of sensation and perception. For, as Dr Reid observes, in the spirit of true philosophy,[3] in the operation of mind, as well as in those of bodies, we must often be satisfied with knowing that certain things are connected and invariably follow one another, without being able to discover the chain that connects them. It is to such connections that we give the name of *laws of nature;* and when we say that one thing produces another by a law of nature, this signifies no more than that one thing which we call in popular language *the cause*, is constantly and invariably followed by another which we call *the effect;* and that we know not *how* they are connected.

In the preceding section we have observed, that in sensa-

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[1] Essays on the Intellectual Powers of Man, essay ii. chap. v.

[2] *Ibid.* essay ii. chap. xiv.

[3] Inquiry into the Human Mind, 4th edit. p. 258.

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tion the mind exerts some energy; and therefore as, upon every hypothesis, perception is a consequence of sensation, it follows, that in perception the mind cannot be wholly inactive. Dr Reid, in his Essays on the Intellectual Powers of Man, seems to affirm that it is. "I see no reason," says he, "to believe that in perception the mind acts upon the object. To perceive an object is one thing, to act upon it is another. Nor is the last at all included in the first. To say that I act upon the wall by looking at it, is an abuse of language, and has no meaning." This is indeed true; it would be a great abuse of language to say that by looking at the wall a man acts upon it; but we do not believe that any man ever said or supposed such a thing. The philosophers whose opinion he is combating might argue in this manner: We are conscious that in perception the mind is active; but nothing can act immediately where it is not; the mind cannot act immediately upon external existence; external existence therefore is not the immediate object of that energy which is exerted in perception. As Dr Reid affirms that external existence is the immediate object of perception, he must deny the first proposition in this argument; for if it be granted, as we have just seen, that in his reply to Dr Porterfield he admits the second, the laws of reasoning will compel him to admit the third.

To say that in perception the mind acts not upon external objects, is a truth in which all mankind are agreed; and it is the very principle from which his antagonists infer that the conviction of the present existence of external objects is not an original and instinctive consequence of sensation, but an early and deep-rooted association, which may be resolved into a process of reasoning. His meaning therefore must be, that in perception the mind does not act at all. But this is directly contrary to his definition of perception, which he calls an act of the mind; and it is likewise contrary to his theory of perception, as it is detailed in the Inquiry into the Human Mind on the Principles of Common Sense. We are there taught, with equal elegance and perspicuity, "that an impression made by an external object upon the organ, nerves, and brain, is followed by a sensation, and that this sensation is followed by the perception of the object." We are likewise taught, that "although the Peripatetics had no good reason to suppose an active and passive intellect, they yet came nearer the truth in holding the mind to be, in sensation, partly passive and partly active, than the moderns in affirming it to be purely passive. Sensation, imagination, memory, and judgment, have, by the vulgar, in all ages, been considered as acts of the mind. The manner in which they are expressed in all languages shows this; for when the mind is much employed in them, we say it is very active, whereas if they were impressions only, we ought to say that the mind is very passive." All this is undeniable; but if sensation necessarily precede perception, and if in sensation the mind be active, what becomes of the assertion that in perception it does not act at all? Indeed we may appeal to the common sense of mankind, whether any thing can be perceived without some mental energy of the percipient. For when the impressions made upon the external senses are faint, in order to be conscious of them an evident exertion is requisite, not of the organ only, but also of the mind, as in perceiving very remote objects and sounds; but when the impressions are stronger, the perception is involuntary and unavoidable, as has been already explained in the preceding section.

Old theory of perception.

It being thus certain that in perception the mind both acts and is acted upon, and it being universally acknowledged that nothing can act where it is not, we feel ourselves compelled to admit, with the Cartesians, that in perception the conviction of the present existence of external objects is not original and instinctive, but the consequence of an early and unavoidable association of certain sensations with the causes which produce them. In this opinion we are still more confirmed by the well-known fact, that particular pressures upon the organ, nerves, and brain, excite not only sensations, but even perceptions of objects apparently external, when no such objects are within the reach of our senses. Thus,[1] if a man in the dark press either corner of his eye with his finger, he will see a circle of colours like those in the feather of a peacock's tail, though no such external object be before him, and though the room be so dark that nothing external could possibly be discerned. Again, if a burning coal be nimbly moved round in a circle, with gyrations continually repeated, the whole circumference of the circle will at once appear on fire, though it is certain that there can really be no fire but in one portion of that circumference, equal in length to the diameter of the coal. These are facts known to all mankind, and they are perfectly irreconcileable with the supposition, that the perception of external objects by the sense of sight is original and instinctive; but they are at once accounted for, if it be true that rays of light falling from external objects upon the *tunica retina* agitate the optic nerves and brain, and that such agitations excite sensations in the mind which experience has taught us to refer to external objects, as, under God, their ultimate cause.

But although we have declared ourselves to be in this instance Cartesians, we do not admit all the absurdities which have sometimes been imputed to that system of perception. We do not believe that external objects are perceived by means of images of them in the mind or the brain; nor do we think that Descartes or Locke has anywhere affirmed that they are, otherwise than by an expression obviously figurative, denoting, not that the actual shapes of things are delineated in the brain or upon the mind, but only that impressions of some kind or other are conveyed to the brain by means of the organs of sense and their corresponding nerves; and that between these impressions and the sensations excited in the mind, there is a real, and in our present state a necessary, though unknown, connection.[2]

That theory fairly stated.

Upon the whole, we think that there is good evidence for believing, that in perception the process of nature is the following: First, if the object be not in contact with the organ of sense, there must be some medium which passes between them; as, in vision, the rays of light; in hearing, the vibrations of elastic air; and in smelling, the effluvia of the body smelled; otherwise we have neither sensation nor perception. Secondly, there must be some action or impression upon the organ of sense, either by the immediate application of the object, as in the two senses of touch and taste; or by the medium interposed between them, as in the other three senses. Thirdly, the nerves which go from the brain to the organ must receive some impression by means of that which was made upon the organ; and by means of these nerves that impression must be carried to the brain. Fourthly, the impression made upon the organs, nerves, and brain, rouses the dormant energy of the mind; and this double action of the mind and the object produces a sensation. And, lastly, as we know by experience that the mind alone cannot, by any exertion of its own, produce one sensation,

[1] Hartley's Observations on Man.

[2] As the view here given of the opinions entertained by Descartes and Locke in regard to the nature of *Ideas* is altogether erroneous, we think it right to refer, for sounder information, to the profound and elaborate article on the *Philosophy of Perception*, contained in the 52d volume of the *Edinburgh Review*.—*Note to the present Edition.*

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and are intuitively certain that nothing can begin to exist without a cause, we infer from the existence of any new sensation the existence of some other cause than the internal energy of the mind from which that sensation proceeds; and this cause experience teaches us to be the external object. This process is carried on so rapidly, and the several parts of it, by being continually repeated, are so closely associated, that, except by a reflex act of the mind, we do not distinguish them from one another, and therefore denominate the whole *perception*.

Shown to differ little from Dr Reid's.

It is with extreme diffidence that we advance a doctrine which Dr Reid has controverted; but he differs from us only in the last stage of the process,[1] where he supposes sensation and perception to be two simple and independent acts of the mind. Yet he sometimes expresses himself as if he thought, as we do, that in perception the belief of the present existence of external objects is rather the result of experience, than an instinctive persuasion. Thus, speaking of the perception which we have in smelling a rose, he says,[2] "Perception has always an external object, and the object of my perception in this case is that quality in the rose which I discern by the sense of smell. Observing that the agreeable sensation is raised when the rose is near, and ceases when it is removed, I am led by my nature [we think *by experience* would have been more proper] to conclude some quality to be in the rose, which is the cause of this sensation. This quality in the rose is the object perceived; and that act of my mind, by which I have the conviction and belief of this quality, is what in this case I call perception." Again, he says that "three of our senses, viz. smell, taste, and hearing, originally give us only certain sensations, and a conviction that these sensations are occasioned by some external object. We give a name to that quality of the object by which it is fitted to produce such a sensation, and connect that quality with the object and with its other qualities. Thus we learn, that a certain sensation of smell is produced by a rose; and that quality in the rose by which it is fitted to produce this sensation we call the smell of the rose. Here it is evident that the sensation is original. The perception that the rose has that quality which we call its *smell*, is acquired."

To this doctrine no Cartesian could reasonably object; for it is the very account which Descartes himself would have given of perception by the organ of smell, as it resolves such a perception into an early association between a certain sensation and that external quality from which we know by experience that the sensation proceeds. Indeed this excellent author repeatedly affirms that every different perception is conjoined with a sensation which is proper to it; and that the one is the sign, and the other the thing signified. He likewise doubts[3] whether children, from the time that they begin to use their senses, make a distinction between things which are only conceived or imagined, and things which really exist. But if the conviction of the present existence of external objects were in perception *instinctive*, we cannot see how there could be room for such a doubt; for the mere senses of children are as perfect as those of full-grown men, and they know well the difference between actually sucking their nurses and only thinking of that operation, though they be not capable of expressing that difference in language.

Something exists besides perception and sensation.

But if in perception our conviction of the present existence of external objects be not instinctive, what, it may be asked, is the evidence that such objects really exist? This question we shall partly answer in the following section, and more completely when we come to examine Berkeley's theory of the non-existence of matter; but, from what has already been said, it is sufficiently evident, that every sensation compels us to believe in the present existence of something different from ourselves, as well as from our sensations.

Objects of the respective Senses.

SECT. III.—*Of the Objects of each Sense respectively.*

Touch.

Hitherto we have considered sensation and perception in general, and shown that it is not by instinct that we perceive the existence of external objects. This will appear more clearly, if we can ascertain the precise nature of that information which each sense affords us; and in order to this, we shall begin with the sense of touch, not only because it is that which is certainly first exercised, but also because there is a meaning, in which all the others may be resolved into it.

Nature of heat and cold.

By means of touch we perceive many things, of which the chief are, heat and cold, hardness and softness, roughness and smoothness, extension, figure, solidity, and motion. Of these perceptions, some are immediate; and others, as we are persuaded, early associations, which may be resolved into a process of reasoning. The perceptions of heat and cold are immediate. When a person for the first time in his life approaches the fire, he feels heat; and when he is first exposed to the frost, he feels cold. What then are heat and cold, and where do they reside? They are obviously the reverse of each other; but are they external objects, or mere sensations in the mind? They are undoubtedly sensations which have no existence but when they are felt. To every man not altogether a stranger to these speculations, this proposition is self-evident; but to the bulk of the people it appears an extravagant paradox. To make it plain, however, to the meanest capacity, it is sufficient to observe, that at a certain distance the fire has no perceptible influence upon any person; if that distance be lessened, we feel an agreeable warmth; approach a little nearer, and the warmth becomes disagreeable; and, still nearer, it will rise to pain. No man supposes the pain inflicted by a sword to exist in the sword, or anywhere else but in a sentient being. It is equally absurd to suppose pain to exist in fire, or anywhere else but in a sentient being. But that which at one distance is pain, at another is only agreeable warmth; and since warmth and pain are only different degrees of the same feeling, it is equally absurd to suppose the one, as the other, in the fire. What then is the object of sense when we feel heat? There is obviously no object whatever beyond the present sensation.

Their external causes.

But has the sensation of heat no cause independent of us? Undoubtedly it has, and experience teaches us that the cause is in the fire. We know that we cannot produce the sensation of heat in ourselves by any mental energy of our own; and we are intuitively certain that nothing can begin to exist without some cause. A man upon the top a mountain covered with snow may imagine or remember what he felt when in the neighbourhood of fire, and thus have in his mind what is called an idea of heat; but that idea will not warm him like the actual sensation, which no exertion of his own can in such circumstances produce. When he leaves the mountain, however, and approaches the fire, he feels the sensation actually produced as often as he makes the experiment. He is, therefore, under the necessity of inferring, that in the fire there is some power or quality which, acting either mediately or immediately upon his sense of touch, excites the feeling

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[1] See Inquiry into the Human Mind, 4th edit. p. 383. [2] Essays on the Intellectual Powers of Man, essay ii. chap. xv. and xxi. [3] Essays on the Intellectual Powers of Man.

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which is called *heat*. What that power is, we shall perhaps never be able to discover; but it is self-evident, that it is neither heat nor the resemblance of heat, though in vulgar language it is known by that name.

The same reasoning holds good with respect to cold. There is at certain times, and in certain countries, some power in the air which congeals water and causes cold; but that power is as different from the sensation of cold, as the power of fire is different from the sensation of heat, or the point of a sword from a flesh wound.

The perceptions of extension, figure, &c. not immediate.

By the sense of touch we perceive extension, figure, solidity, &c.; but we do not perceive them immediately, as we perceive heat and cold, for extension, figure, and solidity are not sensations. Those perceptions, then, must be acquired; and to ascertain more clearly the manner in which we acquire them, let us suppose a man from his birth destitute of the sense of sight and the power of local motion, but possessed of intellect and every other faculty which we enjoy. Such a person, it is obvious, would be capable of every sensation and perception which is original to us, except the perception of colours; but we doubt whether it would be possible to give him perceptions of extension, figure, and solidity. Let us try; and as he cannot move a single limb or member of himself, let us suppose a solid substance of small dimensions to be gently pressed against any part of his body. What would such pressure communicate to him? We think it could communicate nothing but a new sensation, to which, as it is neither pleasing nor painful, no name has hitherto been given, except the general one of *feeling*. This sensation he would not know whether to refer to an external or internal cause, or rather he could have no notion whatever of an external cause, though he would at the same time be conscious that the new sensation was not excited by any energy of his own will. Were the pressure to be gradually increased till it rose to pain, our blind man would still be conscious of nothing but a sensation, which could not lead him to the notion of extension, figure, or solidity, because mere sensations cannot be conceived as either solid or extended. Let us next suppose the pressure to be applied successively to different parts of his body; he would now indeed be conscious of successive sensations, but he could not assign to them either extension or place; for it has been already shown that the external parts of the body are not themselves sentient, and it shall be shown afterwards, that to a man who has never perceived motion, place is absolutely inconceivable. Lastly, let us suppose the dimensions of the pressing substance to be greatly enlarged; what would then follow? Nothing, we apprehend, but an increase of pain; for though his whole body were pressed *ab extra*, the pressure could affect the individual being which is sentient, not more extensively, but only more violently. It appears, therefore, that a man blind from his birth, and destitute of the power of local motion, could never be made to perceive extension, figure, or solidity.

How they are acquired.

Let us now suppose this man to receive by a miracle the use of his limbs, and to be suddenly prompted, by some instinctive impulse, to arise and walk. As long as he met with no obstacle in his way, he would not, we apprehend, acquire by this exercise any correct notions of extension or figure; but were a stone or log of wood of considerable dimensions to be laid across his usual walk, the case would soon be altered. He would feel himself interrupted in his course, and he would at the same instant recognise his wonted sensations of touch. After being twice or thrice thus interrupted, he would learn from experience that the interruption or resistance proceeded from the same cause which in this instance communicated to him the sensation of feeling; and were he to run his hand along the surface of the log or stone, he would perceive the resistance and the sensation continued. As every effect must have an adequate cause, this continued resistance would compel him to believe the continuity of something external in every direction in which he felt his hand resisted; but such continuity of being is all that is meant by the word extension. At the very same time, and by the very same means, he would gradually acquire the perception of figure; for, by running his hand in every direction over the surface of the obstacle which opposed him, he would soon perceive it on all sides limited; but the limits of extension is a phrase of precisely the same import with figure. It appears, therefore, that without the power of local motion, men could never, by the sense of touch, acquire the notions of extension and figure; and the same will be found to be the case with respect to hardness and softness.

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Hardness and softness, how perceived.

When we press our hand gently against a stock or a stone, we feel a sensation which is neither painful nor pleasing. When we press it more violently, the sensation becomes painful, and we experience in the object a resistance which we have not power to overcome. When we press butter or pomatum very gently, we have a sensation in all respects similar to that which we felt when we gently touched the stock or the stone. But when we press the butter with violence, we feel no pain, and experience little resistance; for the parts of which it is composed give way before the hand, though the parts of the stock or the stone remain fixed and immoveable. That the parts of one body should thus resist a pressure to which the parts of another so readily yield, must proceed from some difference in the texture of the two bodies; for by the sense of touch we perceive the effects to be different, and are therefore certain that they must proceed either from different causes, or from the same cause operating with different degrees of force. That particular texture which makes the parts of a stone resist the pressure of touch, we call hardness; and the texture which makes the parts of butter or pomatum give way to touch, we call softness. But what hardness and softness are in themselves, touch cannot inform us; for they are neither sensations, nor similar to sensations. We acquire, however, by experience, so complete notions of hardness and softness, that every one who understands the English language perfectly knows the meaning of these words as soon as he hears them; and when he is told that one body is hard and another soft, he knows with absolute certainty that the meaning of the assertion is, that the parts of the body which is said to be hard are held together by some unknown cause operating forcibly, and that the parts of the other are held together by the same or a similar cause operating with less force.

Roughness and smoothness.

We acquire the notions of roughness and smoothness in the very same way and by the very same means that we acquire ideas of extension and figure. To describe the process at large would certainly be superfluous; for if what we have said concerning our perceptions of extension and figure be just and intelligible, every one will, without further assistance, discover for himself how he perceives roughness and smoothness. *Motion* shall be considered amongst the adjuncts of body; but in order to understand what body itself is, it will be necessary, before we dismiss the sense of touch, to inquire how we come by the notion of solidity.

Solidity, what, and how perceived.

Solidity is one of those notions, or, in the language of Locke, one of those ideas, which are commonly said to be acquired by the sense of touch. That touch gives the first hint towards our notion of solidity is certainly true, but that hint must be afterwards improved by the intellect, or we never could have an adequate knowledge of what is meant when any thing is said to be absolutely solid. We know by experience that we can at pleasure open

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and shut our empty hand without meeting with any resistance. We know likewise, that when we grasp an ivory ball of three or four inches diameter, no force which we can exert will bring together the several parts of the hand, which were easily brought together when we grasped nothing. In this way do we acquire our first notion of solidity, for the word denotes nothing more in this instance than the power or property of the ball by which our fingers are excluded from the place which it occupies. Solidity differs from hardness in this respect, that hardness results from the strong cohesion of the parts of a hard body, which renders it difficult to change the places of those parts, as they respect one another; whereas solidity respects the whole mass, and is as essential a quality of water as of adamant. A drop of water, indeed, placed between two plain surfaces of marble, will not, like adamant, preclude their contact, because the parts of a drop of water, cohering but loosely to one another, give way to the pressure, and escape in every lateral direction. But if a drop of water be confined on all sides, as in a globe of gold, we know from experience that no force will bring the sides of the globe together without forcing the water through the pores of the metal, and hence we infer solidity to be essential to every corporeal substance.

Thus, then, it appears, that of the objects perceived by touch, not one is immediately perceived except heat, cold, and other sensations. The sensations, as they are not excited by any internal energy of our own, lead us indeed to something external as their cause; and by comparing the different sensations with each other, and observing what effects their external causes have upon our own motions, we are naturally led to conceive these causes as extended, figured, solid, hard or soft, rough or smooth; but it is obvious that this conception is the result of experience, and a process of mental reasoning.

Mere sensations the object of smell.

On the senses of taste, smell, and hearing, it is needless to say much. The immediate objects of these are confessedly sensations which have no existence but when they are perceived, though experience teaches us to refer them all to external objects as their respective causes. With respect to smell, this has been made sufficiently evident in the preceding section; and it is not less evident with respect to taste and hearing.

Taste.

Certain bodies applied to the tongue and the palate, and moistened with the saliva, excite certain sensations, which we call tastes. These sensations, however, are not in the bodies, nor can they have any existence but in a sentient being. They are produced in consequence of impulses on the nerves of the tongue and palate, exciting certain agitations in the brain; but the sensation itself is neither impulse nor agitation. Some substances excite tastes which are agreeable, and others such as are disagreeable, and there are not a few which excite no taste at all. Bodies which applied to the tongue and palate of one man produce tastes that are agreeable, applied to the same organs of another man give him tastes which are disagreeable; and we have all experienced, that the same substance which, when the organs are sound, excites a sweet or pleasant taste, has, when the organs were disordered, excited a taste which was bitter or unpleasant. These facts, which cannot be controverted, afford the fullest evidence, if evidence were wanted, that taste, as we feel it, is no quality of bodies, nor has any existence out of the mind.

Hearing.

The organ of hearing is the *ear*, and its object is *sound*. It is well known that sound is produced by certain vibrations of the air striking the tympanum of the ear, and that these vibrations are caused by the sonorous body. Sound, however, is not vibration, nor the idea of sound the idea of vibration. Sound considered by itself is a mere sensation, which can have no existence but in a sentient being. We know by experience that it is caused by something external, but we know likewise that the effect has no resemblance to the cause. Previously to experience we could not refer sound to any external cause, far less could we discern whether it proceeded from an object above us or below us, on our right hand or on our left. It appears to us self-evident, that if a man born deaf were suddenly made to hear, he would consider his first sensation of sound as originating wholly within himself. Between that sensation and the sensations of touch, taste, smell, and sight, there is no resemblance, nor are there any relations amongst them, which, previously to experience, could induce him to trace them all to external objects as their several causes. Our deaf man might have learned to refer all his other sensations to their true causes, in some such way as we have described under the sense of touch; but sound would be something so new to him, and so totally different from touch, taste, and smell, that he could attribute it to nothing external.

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Different sonorous bodies distinguished by experience.

Experience, however, would soon teach him that the ear is its organ, and the sonorous body its cause; and he would in time learn to distinguish one sound, that of a trumpet, for instance, from another, suppose the sound of a bell, and to attribute each to its proper cause, even when neither the trumpet nor the bell was perceived by his other senses. With respect to sounds which we have been accustomed to hear, this is done so instantaneously, that some philosophers have imagined it to be the effect of an instinctive principle in our nature, totally different from experience, and independent of reason. But the fact is not so. Long before we are capable of making sensation and perception objects of reflection, we have heard the sound produced by the ringing of a bell, and seen the object which produced the sound, so often, that, when we hear a similar sound again, we instantly refer it to a *bell*, though we see not the bell from which it proceeds; but this is the effect of habit, and not of instinct. Had we never perceived a bell whilst ringing, by either of our senses of sight or touch, we could not by the sense of hearing acquire any notion of the figure or texture of the body from which the cause of the sound proceeds, though we had heard that sound every day of our lives. It is, indeed, by experience only that we learn to distinguish by the ear whether a sonorous body be before or behind us, on our right hand or on our left; for we find it always difficult to say from what precise quarter a strange sound proceeds, and this difficulty would be heightened to impossibility had not all sounds something in common. Dr Sparrman relates, that when he first heard the roaring of a lion, he did not know on what side of him to apprehend danger, as the sound seemed to proceed from the ground, and to enclose a circle of which he and his companions stood in the centre. The same thing has happened to every man, when the sound was such as he had never heard before, even though it was neither so loud nor so terrific as the roaring of a lion in a desert wilderness; but with respect to sounds which we are daily hearing on every side of us, we soon learn to distinguish with tolerable accuracy whether they be before or behind us, above or below, on our right hand or on our left. All this, however, is the effect, not of instinct, but of experience improved into habit.

Sight originally perceives nothing but colours.

Sight is justly considered as the noblest and most comprehensive of all our senses. The reason is obvious; for when a full-grown man opens his eyes, he perceives houses, trees, rivers, the earth, sun, moon, stars, &c. and to each of these objects belong figure, extension, colour, &c. which are all perceived instantly by means of this sense. Yet it is certain that the sense of sight does not originally communicate to us so many perceptions; and there is abundant evidence that an infant cannot at first, or for some weeks after its birth, distinguish by vision one object from

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another. Colour is the proper object of sight, and for some time its only object; but colour, as perceived by us, is a mere sensation, which can have no existence but in a sentient being. If this proposition stood in need of proof, we might observe that there are men, and even whole families, who possess the sense of sight in a degree of perfection sufficient for all the purposes of life, and yet cannot distinguish certain colours from each other, blue, for instance, from green, or perhaps from red; and there is no man who can distinguish between some particular shades of blue and green by the feeble light of a candle. Were colours the real qualities of body, this mistake of one for another could never be experienced. No man who possesses the sense of touch ever confounded hardness with softness, a sphere with a cube, or an ell with an inch. The reason is, that hardness and softness, figure and extension, are the qualities of things external; whereas colour being a mere sensation, is nothing but an affection or modification of the sentient being. But it is obvious that sentient beings, according as they differ from one another, may be differently affected by the same external cause, so that one man may perceive that to be green which all other men perceive to be blue. The immediate external cause of the sensation of colour is the rays of light reflected from the body, which in common language is said to be coloured. These rays, falling upon the pupil of the eye, are refracted differently, according as their incidence is more or less oblique, into points on the retina, where they form a picture of the external object; and from the picture, by means of the optic nerve, is communicated to the brain some impulse or agitation, which produces vision, or the perception of colour. As rays of light are corporeal substances, it is obvious that they can act upon body only by impulse; but between impulse and the various sensations of red, green, blue, yellow, &c. there is no resemblance. (For the laws of reflection and refraction, and for the structure of the eye, see Optics and Anatomy.) That which we have to inquire into at present is, how we learn, by means of the sense of sight, to perceive the figure, magnitude, motion, and distance of external objects, or indeed to distinguish one object from another.

Perception of figure, magnitude, &c. how acquired.

A ray of light proceeding, as all rays do, in a straight line, must, however great its length, affect the eye, retina, and optic nerve, as if it were a single point. From this obvious and undeniable fact Bishop Berkeley predicted,[1] that a man born blind, who should be suddenly made to see, would at first perceive nothing without him, would distinguish neither the distance, size, figure, nor situation, of external objects; that he would only see in his eyes themselves, or, to speak more properly, would only experience new modifications in his mind, until, joining touch to sight, he thus formed a communication with the external world, and learned, by the simultaneous exercise of the two senses, that natural language in which the visible is the sign of the tangible. This truth, which was discovered by the bishop merely by contemplating in his own mind the nature of sensation, and the known laws of optics, after having been laughed at for more than twenty years as one of the many dreams of a visionary genius, was completely confirmed by the case of the famous patient whom Cheselden cured of a cataract, and that, too, though the cataract does not produce total blindness; which makes it evident that the first visual perceptions of the patient after his recovery could not be wholly new and unmixed. It may indeed be confirmed at any time by a simple experiment made upon an infant. For several weeks after birth, a child shuts not its eyes upon the sudden approach of an object to them, nor shows the least symptom of distinguishing one distance from another; and it is easy, by a little attention, to observe how it gradually learns to distinguish objects at greater and greater distances. Indeed colour, or the immediate object of sight, being a mere sensation or affection of the mind, can have no natural relation whatsoever to any thing external.

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Perception of distance.

It is plain, therefore, that distance is in its own nature imperceptible to the eye, and yet it is often perceived by sight. How is this done? We think, in the following manner. Distance is one mode of extension, which, as we have already seen, is perceived by means of touch. Of short distances, our first ideas are doubtless acquired by the stretching out and drawing back of our arms; and these ideas are soon so connected with certain sensations which we have in actual vision, that the latter instantly suggests the former. Thus it is a fact known by experience, that when we look at a near object with both eyes, according as it approaches or recedes from us, we alter the disposition of our eyes, by lessening or widening the interval between the pupils. This disposition or turn of the eye is attended with a sensation of which every man is conscious at the time of vision; and this sensation seems to us to be that which in this case suggests the idea of greater or less distance to the mind. Not that there is any natural or necessary connection between the sensation of which we are conscious, and greater or less distance; for the sensation is wholly internal, and the distance is external: but, because the mind has, by constant experience, found the different sensations occasioned by different dispositions of the eyes to correspond to different degrees of distance in the object, there has grown a habitual or customary connection between those sensations and the notions of greater or less distance. Hence the mind no sooner perceives the sensation arising from the different turn it gives the eyes in order to bring the pupils nearer or farther asunder, than it is instantly impressed with a certain notion of the distance which was wont to be connected with that sensation. Again, an object placed at a certain distance from the eye, to which the breadth of the pupil bears a sensible proportion, being made to approach nearer, is seen more confusedly; and the nearer it is brought, the confusion is always the greater. The reason of all this is known to every optician; but it being constantly experienced by those who never dipped into optics, there arises in the mind of every man an habitual connection between the several degrees of confusion and distance, the greater confusion still implying the less distance, and the less confusion the greater distance. It is of no avail to say, that between confused vision and distance, great or small, there is no necessary connection; for there is as little connection between a blush in the face and the mental feeling of shame, and yet no sooner does a man of observation perceive that particular colour in the face of another, than it suggests to him the notion of that feeling or passion with which he has constantly observed it accompanied.

In these ways, however, we perceive only small distances. Of distances more remote our judgment is formed from other data, and happily these data are not far to seek. It is a fact known to every man who is not totally ignorant of the science of optics, that a greater number of rays fall upon the eye when reflected from a body near at hand, than can fall from the same body at a distance; and as these rays operate by impulse, it is self-evident that the impression must be stronger, and of course the sensation or colour more vivid, when the body is near than when it is distant. Now, having acquired the notion of the true distance of objects by motion and by the sense of touch, and finding, by an uniform experience, that as they are near or far off,

[1] Essay towards a New Theory of Vision.

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the sensation or colour which they excite in the mind through the organ of vision is more or less vivid, these degrees of sensation come to be so closely associated with the respective distances of the object, that the one instantly suggests the other.

How figure is perceived by sight.

It is just so that we perceive figure by sight. Having experienced by the sense of touch that one surface is a square and another a circle, that one body is a cube and another a sphere; and finding our sense of sight differently affected by the square and the circle, by the cube and the sphere; these different affections come to be so closely connected in our minds with the figures of the respective bodies, that, long before we are capable of reasoning on the subject, the one is never present to us without suggesting the other. Nay, so complete in this case is the connection or association, that we cannot even in idea abstract the colour from the figure, though it is certain that colour is a mere sensation, and figure an external quality; that colour alone is immediately perceivable by the eye, and the notion of figure suggested by the colour. We are aware that it has been affirmed, and affirmed with great vehemence, that figures of two dimensions are immediately perceived by the eye, and perceived with greater accuracy than by the sense of touch. But they who insist upon this doctrine affirm likewise, contrary to experience and the clearest reasoning, that the immediate objects of sight are external, and that colour is a quality of bodies. In the arguments, too, by which they support their hypothesis, they seem to confound sight as an affection of the mind, with the picture on the bottom of the eye, as if the retina were the sentient being; whereas the retina and the picture are no more than instruments of sensation. It is indeed a fact that the picture has the same figure nearly with the plane of the object which is presented to the eye; as when the object seen is a sphere, the picture is a circle variously shaded in colour. It is likewise a fact that the picture is enlarged in proportion as the object is brought near, and diminished as it is carried to a distance. But these facts are known only to persons who are skilled in optics; and therefore it is evident, that though calculations may be raised from them by mathematicians to determine the distance and figure of external objects, they cannot possibly be the data from which distance and figure are inferred by the vulgar, who know not that such pictures on the retina exist. And besides all this, it is universally known that a painter, by laying on his colours properly, can make a plain square surface appear to the eye in certain positions as an oblong or as a cube, and a plain circular surface as a concave or a convex hemisphere. But not one of these things could possibly be done were figure, or indeed any thing else than colour, the immediate object of vision.

Magnitude.

As we see distance and figure, so we see magnitude; and we see both in the same way that we see shame or anger in the looks of a man. The impression made upon the bottom of the eye by rays reflected from a large magnitude, must necessarily be different from the impression made by rays reflected from a magnitude that is less. This is self-evident; and since the impression *ab extra* is in some way or other the cause of that sensation, which is all of which we are originally conscious in vision, it is obvious that the sensation, like every other effect, must correspond to the cause from which it proceeds. Being therefore conscious of different sensations, and having, at an earlier period than we distinctly remember, learned by experience to refer them to different magnitudes, no sooner is each sensation excited than it suggests the notion, or, if you please, the perception, of that magnitude with which it is connected. So completely is this association fixed in the mind, that when we look at a known object, its real magnitude appears to be as instantly observed as its colour, whilst we hardly attend at all to the particularity of the sensation by which the magnitude is suggested. It is, indeed, customary with writers on optics to distinguish between tangible and visible magnitude, as if any kind of magnitude were the immediate object of vision. But this is not so; for magnitude is something external, whereas the immediate object of vision is a mere sensation. What has introduced into science this mode of speaking is probably the fact, that, as we approach a distant object, it appears to the eye larger and larger at every step, and less and less as we recede from it; whereas the tangible magnitude of an object remains always the same. The reason of this apparent change of magnitude to the eye, according to the distance at which any particular object is viewed, is, that from a near object rays of light fall in greater numbers and more diverging than from the same object viewed at a distance. This of course alters the nature of the visible sensation. Each common sensation is in the mind closely linked with a particular notion of magnitude; and by the exercise of sight and touch we have learned from experience that the particular sensation caused by diverging rays must be referred to a larger magnitude than that which is caused by parallel rays proceeding from the same distance.

Retention and Ideas.

Visible sensations a kind of natural language.

Upon the whole, then, we think ourselves entitled to conclude, that the proper and original objects of vision constitute an universal language of the Author of Nature, by which we are instructed how to regulate our actions, in order to attain those things which are necessary to the preservation and well-being of our bodies, as also to avoid whatever may be hurtful or destructive to them. It is principally by the information of this language that we are guided in all the transactions and concerns of life; and the manner in which it signifies and marks to us the objects which are at a distance, is similar to that of languages and signs of human appointment, which do not suggest the things signified by any likeness or identity of nature, but only by a habitual connection, which experience has made us to observe, between them. This language of the eye, like the language of the tongue, suggests by one sensation what may be resolved into a variety of perceptions. A tree is composed of a trunk, branches, leaves; it has colour, figure, size; and all these things are at once suggested to the mind by the two words *spreading oak*. Just so it is with respect to vision; the sensation received by the eye suggests at once the trunk, branches, leaves, colour, figure, and size of the oak, and suggests them all as the qualities of one object.

CHAP. II.—OF RETENTION AND IDEAS.

Sensations and perceptions remain for a time after the removal of their objects.

From the experiment with the burning coal already mentioned, it is apparent the sensations excited through the eye, together with their corresponding perceptions, remain in the mind for a short time after the external exciting cause is removed. The same thing appears from another experiment, which was first made by Sir Isaac Newton, and which every man may repeat for his own satisfaction. It is universally known,[1] that a proper mixture of the seven original colours, red, yellow, green, blue, &c. constitutes that uniform appearance which we call white. But when these colours are made to pass in rapid succession before the eye, they excite the very same perception as when they are properly mixed, which is a satisfactory proof that the impression made by each separate colour remains in the brain until a revolution of all the colours is completed;

[1] Hartley on Man.

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for nothing but the impression of all the colours at once can produce the sensation and perception of white. Indeed no person capable of paying the proper attention to these things can keep his eye fixed upon a luminous object, and afterwards shut it, without experiencing that the sensation and perception remain for some time after the external object is shut out, and that they go off gradually till they leave behind them the mental appearance, which is properly called an idea of the object.

The same continuance of the sensation after the removal of its cause is equally observable in the sense of hearing; for every sound which we hear is reflected by the neighbouring bodies, and therefore consists in reality of a variety of sounds succeeding each other at different distances of time, according to the distances of the several reflecting bodies. Yet this causes no confusion or apparent complexity of sound, unless when the distance of the reflecting bodies is very considerable, as in spacious buildings.

With respect to the continuance of the sensation of touch, doubts have been started; but for these there is as little room as for doubts as to the continuance of the sensations of seeing and hearing. The continuance of heat after the heating body is removed, and of the smart of a wound after the instant of infliction, are proofs that every sensation of touch does not vanish with its cause. A man unused to the motion of a ship or coach, after having been a day at sea or on the road, feels or imagines he feels the rolling of the ship or the jolting of the coach after he is in bed and actually at rest. Of these facts we know not what other account can be given, than that the agitation in the brain, which is the immediate cause of the sensation of touch, remains for some time after the external cause of the agitation is removed.

As to the senses of taste and smell, Dr Hartley seems to think that there is no clear and direct evidence for the continuance of their sensations after their proper objects are removed; but in this instance the ingenious author does not do justice to his own theory. Let any man eat onions, garlic, or any other thing of a very pungent taste, and immediately wash his mouth with fresh water, so that he may be sure no part of the sapid body remains on his tongue or palate. According to this doctrine, the taste of the onion or garlic should instantly vanish with its object; but the fact is otherwise. Whoever shall make the experiment, will find that the sensation remains a considerable time; not indeed in its original force, but weakened no more than what it must necessarily be by the introduction of a new sensation excited by the water. It is more difficult to ascertain the permanency of smell; but analogy inclines us to believe, that in this particular it resembles the other senses, though we know not how to direct the reader to an experiment which will give him absolute conviction.

Hence we have the power or faculty called memory.

Whether the cause of these continued sensations, after the removal of their objects, be in the brain alone, in the mind alone considered as an immaterial being, or in both together, is of very little importance; because, taking the mind and its internal organs as one metaphysical whole,[1] it matters not to our present inquiry where this retentive power resides, as long as it can be proved to exist within us. For it seems evident, that what has the faculty of retaining a sensation when no longer acted upon by the object which excited it, must also have a power to preserve the vestiges of that sensation, even after the sensation itself shall be entirely obliterated. This is in fact the case with the mind. When an object which we have once perceived is most remote from our thoughts, we are certain that there is within us a capacity, disposition, tendency, or power, by which a representation of that object may be at any time revived and presented to the intellect. Thus the same inherent power of the mind and its internal organs, which retains a sensation and perception in the absence of the object by which they were excited, can also reproduce that perception, or bring into the view of the intellect something exactly similar to it. The reproduction will not indeed be so lively as the original perception when accompanied with its corresponding sensation, because sensation and actual perception are effected by a double cause, the action of the external object upon the organ, nerves, and brain, and the corresponding energy of the mind or sentient principle; whereas, in the reproduction, the mind seems to act solely by its own power, and certainly without the assistance of external objects. This reproductive power is commonly called *memory*. By many of the ancient philosophers, and by M. Schwab with one or two others amongst the moderns, it is called imagination. We do not choose either to revive antiquated modes of expression, or to introduce innovations of our own; but as we cannot disapprove of the ancient phraseology, after the definitions which the reader will by and by find of imagination, and memory, and recollection, as given by Mr Harris, we have prefixed to this chapter the general title of retention, which comprehends them all.

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Opinions of philosophers as to memory.

When one recalls an object of sight by the power of memory, it appears to him precisely the same as in the original survey, only less distinct, and with a conviction (which is perhaps the result of experience) that the real object is not immediately before him. How is any object recalled by the power of memory? Does the man endeavour to form in his mind a picture or representative image of the object? Let us listen to the answers given by different philosophers to this question.

The Peripatetics and Platonists distinguish between imagination and memory.

The sentiments of the Peripatetics, as expressed by Alexander Aphrodisiensis, one of the earliest commentators on Aristotle, are thus translated by Mr Harris in his Hermes. "Now, what fancy or imagination is, we may explain as follows: We may conceive to be formed within us, from the operation of the senses about sensible objects, some impression (as it were) or picture in our original sensorium, being a relict of that motion caused within us by the external object; a relict which, when the external object is no longer present, remains, and is still preserved, being as it were its image; and which, by being thus preserved, becomes the cause of our having memory. Now such a sort of relict, (and as it were) impression, they call fancy or imagination." A passage from the *Alcinous* of Plato, as rendered into English by Dr Reid,[2] shows that, in this theory, as well as in that of perception, the Platonists agreed with the Peripatetics. "When the form or type of things is imprinted on the mind by the organs of the senses, and so imprinted as not to be deleted by time, but preserved firm and lasting, its preservation is called *memory*."

Mr Harris, who was deeply read in the ancient philosophy, and who considered the authority of Aristotle and Plato as superseding all reasoning and all inquiry, after justly observing, that if the soul had no other faculties than the senses, it could never acquire the least idea of time, expresses himself thus on the subject before us. "But, happily for us, we are not deserted here. We have, in the first place, a faculty called imagination or fancy, which, however as to its energies it may be subsequent to sense, yet is truly prior to it both in dignity and use. This it is which retains the fleeting forms of things, when things themselves are gone, and all sensation is at an end. That this faculty, however connected with sense, is still perfectly different, may be seen from hence. We have an imagination of things that are gone and extinct; but no such things

[1] See an Essay on the Reduction of the Faculties of the Mind, by M. Schwab.

[2] Essays on the Intellectual Powers of Man.

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can be made objects of sensation. We have an easy command over the objects of our imagination, and can call them forth in almost what manner we please; but our sensations are necessary when their objects are present, nor can we control them except by removing either the objects or ourselves. As wax would not be adequate to its business of signature, had it not a power to retain as well as receive, the same holds of the *soul* with respect to sense and imagination. *Sense* is its receptive power; *imagination* its retentive power. Had it sense without imagination, it would not be as wax, but as water; where, though all impressions may be instantly made, yet as soon as made they are entirely lost. Thus, then, from a view of the two powers taken together, we may call *sense*, if we please, a kind of transient imagination; and *imagination*, on the contrary, a kind of permanent sense."

Great part of the office which is here assigned to imagination is in common English attributed to memory; but between these two faculties, as well as between them and recollection, the author accurately distinguishes thus. "When we view some relict of sensation reposed within us, without thinking of its rise, or referring it to any sensible object, this is *fancy* or *imagination*. When we view some such relict, and refer it withal to that sensible object which in time past was its cause and original, this is *memory*. Lastly, the road which leads to memory through a series of ideas, however connected, whether rationally or casually, this is recollection."

Objections to their theory.

Of this theory we shall only remark, that if we could understand the words picture and form in a metaphorical sense, as candour obliges us to understand Locke's images in the mind, then the doctrine of Alexander Aphrodisiensis would be very little wide of the truth. Experience teaches us that memory as well as perception depends upon the state of the brain; and as it is undeniable, that when a man to-day contemplates an object which he perceived yesterday, or at any former period, he has a view of it in all respects similar to the original perception, only fainter and less distinct, it is extremely probable, that an impression *ab extra*, which produces a sensation and perception, leaves behind it some tendency in the brain to vibrate, as in the actual sensation, and that this tendency is carried into effect by the internal energy of the mind itself. But in the Peripatetic philosophy, pictures and forms in the sensorium were considered as real things, and by no means as metaphorical expressions. This is evident from their being constantly compared to the impression of a seal upon wax, and from their converting the *materia prima* from something which can neither be seen nor felt, into visible and tangible body, of which we shall treat afterwards. Now it being certain, that upon a being immaterial no corporeal form can be impressed, and repeated dissections having shown that no such forms are in fact impressed upon the brain, this whole theory is at once overturned.

Objections to Locke's doctrine concerning memory.

Modern philosophers, having denied that there are real images or forms in the mind during the immediate act of perception, cannot, consistently with themselves, admit such images in the act of retention, or when those things which were formerly objects of perception are recalled to the mind by the power of memory. Mr Locke's doctrine is, "that the mind retains these simple ideas which it first received from sensation or reflection, two ways: first, by keeping the idea which is brought into it for some time actually in view, which is called *contemplation*; and, secondly, by the power which we have to revive again in our minds those ideas which, after imprinting, have disappeared, or have been, as it were, laid out of sight; as when we conceive heat or light, yellow or sweet, the object being removed. This," he says, "is *memory*; which is, as it were, the storehouse of our ideas."[1]

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To explain this more fully, he immediately adds the following observation. "But our ideas being nothing but actual perceptions in the mind, which cease to be any thing where there is no perception of them, this laying up of our ideas in the repository of the memory signifies no more than this, that the mind has a power in many cases to revive perceptions which it has once had, with this additional perception annexed to them, that it has had them before. And in this sense it is that our ideas are said to be in our memories, when indeed they are actually nowhere; but only there is an ability in the mind, when it will, to revive them again, and, as it were, paint them anew on itself, though some with more, some with less difficulty, some more lively and others more obscurely. And thus it is, by the assistance of this faculty, that we are said to have all those ideas in our understandings, which, though we do not actually contemplate them, yet we can bring in sight, and make appear again, and be the objects of our thoughts, without the help of those sensible qualities which first imprinted them there."

To attempt a defence of the accuracy of this language would be vain; but as the author's meaning is sufficiently obvious, his expressions may be easily and certainly corrected. Had Mr Locke said, "But our ideas being nothing but scenes or appearances in the mind, which cease to be any thing when there is no perception of them, thus laying up of our ideas in the repository of the memory signifies no more but this, that the mind has a power, in many cases, to revive scenes which it has once viewed, with this additional perception annexed to them, that it has viewed them before," there would have been no room for the many petulant remarks which have been made upon the passage. But against this account of memory a much heavier charge has been brought than that which regards the propriety of the language. It has been said, that the additional perception, which, according to Locke, attends the revival of our ideas by the power of memory, "would be a fallacious perception, if it led us to believe that we had them before, since they cannot have two beginnings of existence: nor can we believe them to have two beginnings of existence; we can only believe that we had formerly ideas or perceptions very like to them, though not identically the same." Let us examine this question somewhat narrowly; for if it be really true, that, in the sense in which the word *same* is here used, we cannot twice contemplate the same idea, all confidence in memory would seem to be at an end.

The objection obviated.

Suppose a man to stand upon some of the rising grounds about Edinburgh, the Calton Hill, for instance, and from that eminence to view the glorious prospect of the coast of Fife, the ocean, the Frith of Forth, and the little islands scattered in the Frith. Let him go away, and return next day to the same place and look the same way; we would ask whether he has the same view or perception which he had the day before? The man must surely be very captious who would say that he has not; and yet it is certain that the energy of mind by which he perceives on one day cannot be identically the same with that by which he perceived on another; nor are the rays of light which fall upon his eyes on the second day, identically the same with those which fell upon his eyes and occasioned vision on the first day. Let the same man now shut his eyes, and contemplate the various objects at which he had been just looking. They will appear to him in every respect the same as when viewed by means of his organs of sight, only fainter and less distinct, with this additional convic-

[1] Essay, book ii. chap. x.

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tion, that the immediate objects of his present contemplation are not real external things, but ideas or mental representations of those things which had so lately been the objects of his sight. Let him think no more about the matter for some days, and then exert his powers of memory. We have no hesitation in saying, that, in the sense of the word *same*, as used by Mr Locke, the very same ideas will recur and be present to his intellect which were present to it at the former contemplation. The second energy of memory or imagination, or whatever it may be called, is not indeed identically the same with the first; nor is that agitation or motion, or whatever other affection of the brain is necessary to memory, identically the same at the second time as at the first; but the mind, exerting itself in the very same manner at the one time as at the other, produces the same kind of agitation in the brain, and is itself affected in the very same way at the second as at the first exertion. Whence it follows, that the second ideal scene will be as much the same with the first, as the second actual perception is the same with the first; and the two ideal scenes, and the two actual perceptions, are respectively said to be the same with each other, only because they impress the mind with a conviction that they were occasioned by the same external objects.

But though we think Mr Locke's doctrine with respect to memory may be thus easily vindicated from the charge of fallaciousness, we must acknowledge that to us it appears not to be of much value. It teaches nothing, but that the mind has a power to retain ideas of those objects which it formerly perceived, and in many instances to recall them as occasion may require. But these are truths known to all mankind, to the clown as well as to the philosopher.

The opinion of Hume.

Philosophers in general have paid less regard to the retentive faculties of the mind than to its original powers of perception. Perhaps they imagined, that as memory depends upon perception, and in some respects appears to resemble it, a competent knowledge of the nature of the former faculty would lead to that of the second. Be this as it may, Mr Hume, who was at some pains to detail his notions of perception, has, in his Philosophical Essays, only dropt, concerning memory and imagination, a few hints, so loosely thrown together, that, if he had not elsewhere expressed himself with more precision, it would have been difficult to discover his real meaning. According to him, that which is commonly called the perception of an external object, is nothing but a strong impression upon the mind; and that which is called the remembrance of a past object, is nothing but a present impression or idea weaker than the former. Imagination is an idea weaker than the idea or impression which he calls memory. This seems to be a wonderful abuse of language. Impressions are not perceptions; and, if possible, they can still less be called ideas, which are but secondary perceptions. It is likewise far from being true, that an idea of imagination has necessarily less vivacity than an idea of memory. We have seen Mr Hume, and have at the present moment an idea of his form and dress. We can likewise imagine to ourselves a centaur; and though a centaur was never seen, and therefore cannot be an impression repeated by memory, our idea of the monster is much more lively and distinct than that of the philosopher.

Of Reid.

Dr Reid, having observed of memory,[1] that it is by it we have an immediate knowledge of things past; that it must have an object; that in this respect it agrees with perception, but differs from sensation, which has no object but the feeling itself; and that every man can distinguish the thing remembered from the remembrance of it; proceeds to inquire what memory is. And, "First," says he, "I think it appears that memory is an original faculty given us by the Author of our being, of which we can give no account but that we are so made. The knowledge," continues he, "which I have of things past by my memory, seems to me as unaccountable as an immediate knowledge would be of things to come; and I can give no reason why I should have the one and not the other, but that such is the will of my Maker. I find in my mind a distinct conception and a firm belief of a series of past events; but how this is produced I know not. I call it memory; but this is only giving a name to it; it is not an account of its cause. I believe most firmly what I distinctly remember; but I can give no reason of this belief. It is the inspiration of the Almighty which gives me this understanding. When I believe the truth of a mathematical axiom or of a mathematical proposition, I see that it must be so; every man who has the same conception of it sees the same. There is a necessary and an evident connection between the subject and the predicate of the proposition; and I have all the evidence to support my belief which I can possibly conceive. When I believe that I washed my hands and face this morning, there appears no necessity in the truth of the proposition. It might be or it might not be. A man may distinctly conceive it without believing it at all. How then do I come to believe it? I remember it distinctly. This is all I can say. This remembrance is an act of my mind. Is it impossible that this act should be, if the event had not happened? I confess I do not see any necessary connection between the one and the other. If any man can show such a necessary connection, then I think that belief which we have of what we remember will be fairly accounted for; but if this cannot be done, that belief is unaccountable, and we can say no more than that it is the result of our constitution. Our original faculties are all unaccountable. Of these memory is one. He only who made them comprehends fully how they are made, and how they produce in us not only a conception, but a firm belief and assurance, of things which it concerns us to know."

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On this account of memory we shall not make any remarks. There is a certain sense of the words, in which every thing which the author has said on the subject is undoubtedly just; and it would be very uncandid to take his words in any other sense. But though memory, as it is the result of that constitution which was given us by God, and not the offspring of habit or human contrivance, is unquestionably an original faculty, and though it is therefore impossible to account for it so fully as to silence every inquiry which may be made, yet we could wish that Dr Reid had bestowed a little more pains upon it, in order to discover if possible in what respects it resembles or differs from perception. He has well observed, that there are laws of nature by which the operations of the mind are regulated, as well as laws of nature which govern the material system. As the latter are the ultimate conclusions which the human faculties can reach in the philosophy of bodies, so the former are the ultimate conclusions which we can reach in the philosophy of minds. The more general that these laws are in both cases, the more useful they are, and the more satisfactory; for as they are themselves inexplicable, the fewer they are in number, and the more comprehensive each is, the fewer will those phenomena be for which we can give no account. Thus, as we know not what makes the planets tend to the centre of the sun, or heavy bodies tend to the centre of the earth, we can give no other account of these phenomena but that, as they appear to be of the same kind, it is reasonable to conclude

[1] Essays on the Intellectual Powers of Man.

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that they proceed from similar causes. What the cause is of this tendency of bodies towards each other, we know not. We call it gravitation, and employ it to account for all phenomena of the same kind. In like manner it is universally allowed, that as we know not how mind and matter operate upon each other, there is something in perception wholly unaccountable. That perception follows sensation, and that there is no sensation which is not occasioned by some affection of the brain, proceeding from some impression *ab extra*, we have the evidence of experience; but how a particular affection of the brain should excite a sensation in the mind, we know not, though we may here, as in the corporeal system, attribute similar effects to the same or to similar causes. Thus, if, when we exert an act of memory, we have the same appearance of things as in the original act of perception, the rules of philosophizing authorize us to refer both phenomena to the same general law, just as they authorize us to refer the motion of the planets and of projectiles to the same general law. On the other hand, if we perceive no similarity between memory and perception, we have made no progress in the philosophy of mind; for in that case we have discovered two phenomena proceeding from two causes totally different from each other, and both inexplicable. Although we scarcely hope to throw any light upon a subject which Dr Reid has not attempted to illustrate, we shall state a few facts respecting the memory, and submit to the reader the conclusions to which we think these facts naturally lead.

The appearance of sensible objects when recalled by memory.

1. Objects once perceived by the senses, when recalled to the mind by the power of memory, appear precisely the same as in the original perception, only less distinct. For example, having seen yesterday a spreading oak growing on the bank of a river, and having heard a shepherd play, and handled a square stone, we endeavour to recall to our mind these objects, which are now absent. But how is this operation performed? Do we endeavour to form in our minds pictures of them, or representative images? or does our intellect survey the types or forms which, according to Aristotle, those objects left in the imagination when they were originally perceived? Neither of these things is done. We conceive ourselves as standing in the same place where we stood yesterday; upon which we have perceptions of the objects similar in all respects to the perceptions which we had when we employed our eyes, our ears, and our hands. The tree appears, as it were, before us; faint, indeed, but attended with all the objects which we observed around it yesterday; we seem to hear the sound of the pipe confusedly, and at a distance; to move our hands over the stone, and to feel the same surfaces and the same angles which we felt in the original perception. In this recollection we are not conscious of pictures or images more than in the original survey. The perceptions seem to be those of the tree and river themselves, of the sound itself, and of the stone itself, exactly as at the first; and yet we are satisfied that in the act of remembrance we perceive no such object as a real tree, pipe, or stone. That these are facts, every man must be convinced who attends to the energies of his own mind when exerting the powers of retention; and therefore it is, in our opinion, with no impropriety that Mr Harris says we may call *sense*, if we please, a kind of transient imagination; and *imagination*, on the contrary, a kind of permanent sense; for if these two faculties, as far as the mind or intellect is concerned, be not the same, they seem to resemble each other much.

Ideas that remain longest in the memory.

2. The primary perception of a visible object is more complete, lively, and distinct, and remains longer in the sensorium, than that of any other object. We know likewise by experience, that an idea or secondary perception of a visible object is as much more complete, lively, and distinct, than the idea of any other object, as was the primary perception; and that we remember things which we have seen for a longer time than sounds which we have heard, or than tangible objects which we have only handled. Yet there seems to be a constant decay of all our ideas, even of those which have struck deepest, and in minds the most retentive; so that if they be not frequently renewed by repeated exercise of the senses, or by reflection on those objects which at first occasioned them, the print wears out, and at last there remains nothing to be seen. Concerning ideas, it is easy to remark, that those remain longest and clearest in the memory which are derived from two or more senses, especially if the sense of sight be one of the number, or which are most often refreshed by a return of the objects which produced them. Hence a man has a longer and more distinct remembrance of what he has seen than of what he has only heard, of what he has both seen and felt than of what he has only seen; and the ideas which we have of heat and cold, of hunger and thirst, and of all those things which most frequently affect our senses, are extremely clear, and are never quite lost whilst the mind retains any ideas at all.

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Memory a kind of habit.

3. Memory appears to be a kind of habit, which is not always in exercise with regard to things we remember, but is ready to suggest them when there is occasion. The most perfect degree of this habit is, when the thing presents itself to our remembrance spontaneously, and without labour, as often as there is occasion. A second degree is, when the thing is forgotten for a longer or shorter time, even when there is occasion to remember it, and yet at last some incident, such as a violent passion,[1] which agitates the whole mind and sensorium, tumbles the idea, as it were, out of its dark corner, and brings it into view without any search. A third degree is, when we cast about and search for what we would remember, and after some labour find it out. This searching faculty of the soul is by Aristotle called ἀναμνησις, by Dr Reid and others reminiscence, and by Mr Harris recollection. Should it be said, that what we will to remember we must already conceive, as we can will nothing of which we have not a conception; and that, therefore, a will to remember a thing seems to imply that we remember it already; we answer, with Dr Reid, that when we will to remember a thing, we must indeed remember something relating to it, but we may have no positive idea or conception of the thing itself, but only of the relation which it bears to that other thing which we do remember. Thus, one remembers that a friend charged him with a commission to be executed at such a place, but he has forgotten what the commission was. He applies himself to discover it, and recollects that it was given by such a person, upon such an occasion, in consequence of such a conversation; and thus by a train of thought he is led to the very thing which he had forgotten and wished to remember. To this operation it is not always necessary that the relations between the various ideas which the mind turns over be very close, or have their foundation in nature; for a casual connection is often sufficient. Thus, from seeing a garment, we think of its owner; thence of his habitation; thence of woods; thence of timber; thence of ships; thence of admirals; thence of cannons, iron, furnaces, and forges, &c.

In recollection one idea suggests another, and why?

That, in the process of recollection, one idea should suggest another, may be easily accounted for. When, in perception, our minds are exposed to the influence of external objects, all the parts and properties, and even the accidental variable adjuncts, of these objects, are perceived by full-grown men at the same time; so that the whole group makes but one impression upon our organs of sense,

[1] Reid's Essays on the Intellectual Powers of Man; Locke's Essay, &c.; and Harris's Hermes.

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and consequently upon the mind. By these means all the parts of the simultaneous impression,[1] and consequently of the perception occasioned by that impression, are so intimately associated or linked together, that the idea of any one of them recurring at any future period generally introduces the ideas of all the rest. But as the necessary parts and properties of any thing are more closely linked together, and occur more frequently, than any particular variable adjuncts, it is obvious, that by the idea of any one of these properties, the idea of the rest, and of the object itself, will be more readily introduced than by the idea of any variable adjunct. It seems, however, to be certain, that we have no power of calling up any idea at pleasure, but only such as have a connection, either in nature or by means of former associations, with those which are at any time present to the mind. Thus the sight, or the idea, of any particular person, generally enables us to recollect his name, because his name and his person have been constantly associated together. If that fail to introduce the name, we are at a loss and cannot recollect it at all, till some other associated circumstance help us. In naming a number of words in a sentence, or lines in a poem, the end of each preceding word or line being connected with the beginning of the word or line which succeeds it, we can easily repeat them in that order; but we are not able to repeat them backwards with any ease, nor at all till after many fruitless efforts. By frequent trials, however, we acquire at last a facility in doing it, as may be found by making the experiment upon the names of number from one to twenty. It is indeed, probable, that in the wildest flights of fancy, no single idea occurs to us but such as had a connection with some other idea, perception, or notion, previously existing in the mind, as shall be shown more fully in a subsequent chapter.

Memory depends on the state of the brain.

4. "Memory appears to depend entirely or chiefly upon the state of the brain. For diseases, concussions of the brain, spirituous liquors, and some poisons, impair or destroy it; and it generally returns again with the return of health, from the use of proper medicines and methods. It is observable, too, that in recovering from concussions and other disorders of the brain, it is usual for the person to recover the power of remembering the then present common incidents, for minutes, hours, and days, by degrees; also the power of recalling the events of his life preceding his illness. At length he recovers this last power perfectly, and at the same time forgets almost all that passed in his illness, even those things which at first he remembered for a day or two. Now the reason of this seems to be, that upon a perfect recovery the brain recovers its natural state, and all its former affections and tendencies; but that such affections or tendencies as took place during the preternatural state, *i. e.* during the patient's illness, are obliterated by the return of the natural state."[2] All this we are induced to believe; because, though it is a fact incontrovertible, that in certain diseases the memory is impaired, and recovers its vigour with the return of health, it is not conceivable that the mind itself should suffer any change by diseases, concussions, spirituous liquors, or the like.

External objects leave some permanent effect in the brain.

From these facts we are strongly inclined to conclude, that the power of the mind, or immaterial principle, by which it remembers past events, differs not from that by which it perceives present objects. In perception, impressions are made upon the organs of sense, which are communicated to the brain, and, by some unknown means, occasion sensations which are followed by the perception of the external object. When by the power of memory we recall past objects of sense, the mind has the same view of them as in the original perception, except that they appear fainter, less distinct, and generally more distant. We have, therefore, reason to conclude, that in the act of remembrance the brain is affected in the same way, although not so forcibly, as in perception. That memory depends as much as perception upon the state of the brain, is confirmed by daily experience; and therefore there cannot be a doubt but that external objects, operating upon the senses, nerves, and brain, leave some permanent effect behind them. What that effect precisely is we cannot know, and we need not desire to know; but that they leave some effect we have as good evidence as that the planets are moved round the sun by forces of the same kind with those by which projectiles are moved on the earth. Could we suppose that they leave real prints or impressions behind them, which we confess to be very little probable, memory would seem to be nothing but the perceptive power of the mind turned to those impressions. If the permanent effect of impressions by external objects be, as Dr Hartley supposes, only a tendency in the brain to vibrate as in the original perception, remembrance will result from the mind's operating upon the brain as in actual perception; and the reason that ideas of memory are fainter than perceptions of sense is, that the former are produced by a single, and the latter by a double operation.

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Why memory advances to perfection and then gradually decays.

This theory appears to be greatly confirmed by the well-known facts, that in general children soon commit to their memory any thing which they understand, and as soon forget it; that the powers of memory gradually advance to perfection, and then gradually decay; and that old men remember more distinctly what they perceived in their youth than what they perceived a year ago. For if the memory belonged wholly to the pure intellect, and had no dependence upon the brain, it is not easy to conceive how it should advance towards a state of perfection, and afterwards decay. A being which is unextended and indivisible can suffer no change either in its essence or in its faculties; the ideas which it had once retained it would retain for ever. But if memory be occasioned by some relict of sense left in the brain, it is easy to see how all those changes should take place; and therefore, though we have the weight of Dr Reid's authority against us, we cannot help thinking that Aristotle was in the right when he imputed the shortness of memory in children to this cause, that their brain is too moist and soft to retain impressions made upon it; and that he was likewise in the right when he imputed the defect of memory in old men to the hardness and rigidity of the brain, which hinders it from receiving any durable impression.

Another argument to prove that in remembrance the mind acts upon something left in the brain by the impressions of sense is this, that nothing can act but where it is present. The truth of this axiom is acknowledged by Dr Reid, and we believe by all mankind, except Dr Priestley and one or two others, whose paradoxes we shall afterwards consider. Now it is confessed, that in recollection at least the mind is active; and therefore it must act, not upon an object which has now perhaps no existence, and certainly no immediate existence, but upon something left by that object in the brain or sensorium, to which the mind is intimately present.

By what means we avoid confounding memory with perception.

But if this be so, we may be asked how it comes to pass that men never confound memory with perception, nor fancy that they perceive things which they only remember? If perception be an inference drawn from certain sensations excited by an impression on the brain, and if remembrance result from the mind's operating upon relicts of those impressions, one would think it natural to suppose that in both cases we have actual perceptions, though in the one case the perception must be much more vivid and distinct than in the other. To this we answer, that, previously to all experience, perception and memory are very

[1] Hartley on Man.

[2] Ibid.

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probably confounded; and that we believe a man brought into the world with all his faculties in their full natural perfection would not instantly be able to distinguish what he remembered from what he perceived. This we know to be the case with respect to imagination, a faculty which strongly resembles memory; for in dreams, and sometimes even in waking reveries, we fancy actually that we perceive things which it is certain we can only imagine. A very short experience, however, would enable this newly-created man to make the proper distinction between remembrance and perception. For, let us suppose him to be brought into a dark room, and soon afterwards a candle to be introduced. The candle would give him a visible sensation, though not at first the perception of an external object. Let the candle after some time be carried out; in that case the man would retain a visible idea, which he might confound with the actual sensation. But if, whilst this idea remained in his mind, the candle were brought back, he would instantly feel a difference between the real sensation and the idea, when both were together present in his mind. And having, in some such manner as we have already described, acquired the power of perceiving external objects by means of his senses, he would soon discover, without any effort of his own, the difference between actual perceptions and the ideas treasured up in his memory.

The order of succession in which objects recur to the memory.

The only remaining difficulty which seems to encumber this theory of remembrance is, to account for the order of succession in which objects recur to the memory, and to which we give the name of *time*. But this difficulty will vanish when we have once ascertained what time is. At present it is sufficient to observe, that our perceptions of external objects remain a certain space of time in the mind; that this time is different according to the strength and other circumstances of the impression which occasioned the perception; and that traces of those perceptions or ideas may be recalled after the intervention of other trains of ideas, and at very different intervals. If one look upon a house, and then shut his eyes, the impression which is made upon his mind will not instantly vanish. He can contemplate the house almost as long as he pleases; and, by the help of various associated circumstances, he may recall the idea several years afterwards, and refer it to the original perception.

Brutes have memory.

Before we dismiss the subject of retention, it may not be improper to take notice of the retentive powers of inferior animals. Aristotle, Locke, Dr Reid, and almost every philosopher of eminence, both amongst the ancients and moderns, have maintained that inferior animals have memory as well as men; and indeed we do not perceive how the fact can be denied of the more perfect animals, and those with whose operations we are best acquainted. A dog knows his master again after a long absence; a horse will trace back a road which he has but once travelled, often with more accuracy than his rider; and it is well known that many species of singing birds have a capacity to learn tunes from the human voice, and that they repeat the notes again and again, approaching nearer and nearer to perfection, till at last they sing the tune correctly. These phenomena can be accounted for only by supposing, that in the brains of the several animals traces are left by perception, of the same kind with those which perception leaves in the brain of man, and which are the cause or occasion of his remembrance. With respect to this point, the learned author of Ancient Metaphysics differs from his master Aristotle. He allows that brutes have imagination, but denies that they have memory; "for," says he, "memory necessarily implies a sense of time, and what is first and last; but brutes have no idea of time, or of first and last; and it is certain that they have not consciousness or reflection, by which only they could review their own operations." At the same time he admits, that imagination in the brute serves the purpose of memory in us; for "whenever he sees the object that is painted on his *phantasia*, he knows it again, but without any perception of the time when he first saw it." But that a brute, when he sees the object which is painted on his phantasia, should know it again without referring it to a former perception, is plainly impossible. The recognisance of any thing consists in a consciousness of its having been perceived before; and nothing more than such recognisance is essential to memory. The author's mistake seems to lie in supposing that memory necessarily implies a sense of some determinate portion of past time; but we surely remember many things of which we can only say that we have formerly perceived them, without being able to ascertain the precise period at which we had such perceptions. A child has the use of memory sooner than he acquires the faculty of speech; but he must have spoken and even reasoned before he can have an accurate notion of time, which, as shall be afterwards shown, arises from comparing the fleeting succession of our own ideas with the permanence of ourselves and other objects. The author's distinction between memory and imagination seems to be in every view improper. Aristotle has said, and said truly, that there is memory of ideas as well as of sensible objects, meaning by ideas general conceptions or propositions; but this reviver of his philosophy is inclined to say, "that memory is only of ideas, and consequently belongs only to man; and that imagination is only of sensible objects, and consequently belongs both to man and brute." But surely man remembers what he has seen and felt as well as what he has conceived or thought; and if imagination and memory be properly distinguished by Mr Harris, the reverse of this writer's doctrine must be true, viz. that imagination belongs only to man, and memory of sensible objects both to man and brute. We can contemplate in imagination the idea of a centaur or of a golden mountain; but we cannot be said to remember them, for they were never perceived. That a dog can contemplate in his imagination the idea of a centaur or of a golden mountain, we have not the least reason to suppose; but were he not capable of viewing relicts of sense reposed with him, and referring them to their original causes, he could not possibly recognise his master after a day's absence.

The power of recollection.

Dr Reid and the same author agree with Aristotle in thinking it probable that brutes have not reminiscence, or the power of reflection; but there are many well-attested facts which seem to prove the contrary. We shall here mention one which fell under our own observation. One of the persons concerned in this work was, when a young man, absent for five months from the house of his father. Upon his return, a dog of that species which is commonly called the *shepherd's cur*, and which had been in the possession of his father only a few months before his departure, gazed at him for a few minutes as at any other stranger. The animal then began to walk round him with looks which very soon attracted his notice. This made him call the dog by the name which he bore in the family, and stretch out his hand to caress him, when the creature instantly leaped upon him with all that appearance of attachment which these animals so commonly exhibit upon the return of their master after a few days' absence. If this was not recollection, we should be glad to know what it was, not being able to distinguish it from recollection in men. Indeed, if dogs and some other animals possess, as Aristotle, Locke, and others allow them to possess, the power of memory, and something of ratiocination; and if, as Dr Reid expressly says,[1] "they ex-

[1] Essays on the Intellectual Powers of Man.

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pect events in the same order and succession in which they happened before," it is not conceivable that they can be wholly destitute of reminiscence, or the power of recollection.

Memory capable of improvement.

That memory is a faculty of the first importance, cannot be denied; since it is obvious that, without the power of retaining the ideas and notions which we receive by the senses and other faculties, we never could make any progress in the acquisition of knowledge, but should begin every day, nay, every hour, in the same state of ignorance in which we were born. That it is a faculty capable of improvement by exercise, and that there are some methods of exercise better adapted for this purpose than others, has been shown elsewhere. (See MEMORY.)

CHAP. III.—OF SIMPLE APPREHENSION AND CONCEPTION.

Ideas of sensation first materials of knowledge.

The ideas received into the mind by the senses, and treasured up in the memory and imagination, are the original materials of human knowledge. It is by comparing those ideas with one another, or by analyzing them into their first principles, that we acquire all our knowledge in mathematics and philosophy, and indeed all that knowledge which regulates our conduct throughout life. It must therefore be of importance to trace the progress of the mind in her various operations upon these materials; beginning, as she certainly does, with that which is most simple, and proceeding regularly to those which are more complex and difficult.

Simple apprehension.

Now the first operation of the mind about her ideas appears plainly to be that which logicians term *simple apprehension*. Having yesterday observed a tree or any other object, if we contemplate the idea of that tree to-day as it remains in the imagination, without comparing it with any other idea, or referring it to any external object, we perform the operation which is called simple apprehension. We consider simple apprehension as an operation, because the mind in the apprehension of her own ideas is certainly active; she turns them as it were round and round, and views them on every side.

Different from conception

Simple apprehension is a phrase which is very commonly taken to be of the same import with the word *conception*, and in the ordinary affairs of life no confusion can arise from an indiscriminate use of the two words; but in this article we think it expedient to employ the phrase *simple apprehension* to denote the view or contemplation of those ideas only which the mind by sensation has actually received from external objects; and the word *conception* to denote the view, not only of those ideas, but also of such as the mind fabricates to herself. Thus, a man may conceive a centaur, but we would not choose to say that he may apprehend a centaur; not that there is any impropriety, perhaps, in this last expression, but as there is certainly a difference between apprehending the idea of what has been seen or felt, and conceiving that which never existed, perspicuity requires that these different operations be expressed by different names.

In what sense we conceive objects which never existed.

We have said that the mind may conceive what never existed; and every man may easily satisfy himself that what we have said is true. But although this has been frequently called the creative power of the mind, it has in fact no resemblance to creation. The materials of all our most complex and fantastic conceptions are furnished to our hands by sensation and reflection; nor can we form one simple idea which was not originally received by some of our senses from external objects, or, as shall be shown afterwards, one intellectual notion which was not acquired by reflecting on the operations of our own minds. To explain the process of fantastic conception, it is to be observed, that in every sensible object we perceive at once several things, such as colour, figure, extension, and motion or rest, &c. These are the objects of different senses; but they are not, at least by full-grown men, perceived in succession, but all at once; whence it comes to pass that the memory or the imagination retains not several distinct and disjointed ideas, but the idea of one coloured, figured, and extended object. But when we compare together various objects, or the ideas of various objects, we find that in some respects they agree, and in others disagree; in other words, that several objects affect some of our senses in the same way, and other senses differently. Thus, one globe is black and another white, one black substance is circular and hard, and another square and soft. In the first instance, the two globes affect our sense of touch in the same way, and our sense of seeing differently; in the second, the two black substances affect our sense of sight in the same way, and our sense of touch differently.

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From observing this difference amongst objects by means of the different sensations received from them, the mind learns to analyze its original ideas, which are copies of those sensations, into their first principles, and to combine those principles in such a manner as to form complex ideas of objects which were never actually perceived by the senses. Of the simple and unmixed principles which compose those complex ideas, there is not indeed one which was not originally received by some sense, so that the whole difference between complex ideas fabricated by the mind and those which are the relicts of sensation, consists in the order in which the constituent simple ideas of each are put together. Thus, no man ever saw a mountain of pure gold, and therefore the idea of such a mountain can be in no human mind as a relict of sensation; but we have all seen pieces of gold of different sizes, and we have all seen mountains, and nothing is more easy than to conceive a piece of gold extended on all sides to the size of a mountain, and rising out of the earth. Again, though no person ever saw a centaur, yet it is easy to conceive the upper parts of a man joined to the breast and shoulders of a horse. In these instances the complex conceptions are of things which it is in the highest degree probable never had a real existence, and which it is certain we never perceived as existing; but the simple ideas of which they are composed are the relicts of actual sensations, for every one has perceived as really existing the body of a horse and the upper parts of a man, and when conceiving a centaur, he only conceives them to exist united. That we have not in the imagination one simple and unmixed idea which was not left there as a relict of sense, every man will be convinced who shall try to conceive a simple colour or taste which is totally different from all the colours and tastes, and all the shades and varieties of them, which he has received by sensation; but his simple ideas, though all received from without, he may put together in innumerable ways or modes, differing from any order in which he has ever actually perceived the qualities of external objects existing.

The power of conception limited to possible existence.

Yet even this power of the mind is limited. It is impossible to put together a number of contrary and inconsistent ideas, in such a manner as to form of them one complex conception. No man, for instance, can conceive a thing to be at once white and black, round and square, hard and soft, in motion and at rest. Hence it is a maxim almost universally received amongst philosophers, that although we can conceive many things which never actually existed, yet we can form no ideas but of such things as might possibly exist. A centaur never existed, but it may be conceived; for it is by no means impossible that the head of a man might be joined to the body of a horse; but black snow cannot be conceived, for, in the complex idea denoted by the word snow, whiteness is an essential part, and nothing can be conceived to be both black and white

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at the same time. From this undoubted fact, that we cannot conceive impossible existence, the power of conception has by some writers been in certain instances made a test of truth. "In every idea is implied," says Dr Price,[1] "the possibility of the existence of its object; nothing being clearer than that there can be no idea of an impossibility, or conception of what cannot exist." "It is an established maxim in metaphysics," says Hume, "that whatever the mind conceives, includes the idea of possible existence; or, in other words, that nothing we imagine is absolutely impossible."[2] In a word, it has been admitted by all philosophers, from Pythagoras to Dr Reid, that whatever we can distinctly conceive is possible, although many things may be possible, nay, may really exist, of which we can form no conception.

Dr Reid's opinion of conception controverted.

This axiom has been denied by the author of the Essays on the Intellectual Powers of Man, who affirms that "any two sides of a triangle may be conceived to be equal to the third," as distinctly as "any two sides of a triangle may be conceived to be greater than the third." This assertion proceeding from such a man surprised us as much as any paradox which we ever read; for nothing is more certain than that we ourselves can form no conception of a triangle of which two of the sides are only equal to the third. We can indeed resolve the proposition into its different parts, and form the distinct and independent ideas of a triangle, two sides, and one side, and we can likewise form the general notion of equality; but to combine these ideas and this notion into one individual complex conception is absolutely impossible. A man who knows nothing of triangles, if such a man there be, might believe Dr Reid that it is a figure of which one of its sides is equal to the other two; but such a person would have no conception of the figure itself, and only a confidence in the doctor's veracity.

What is it to conceive a corporeal thing to exist? Is it not to fancy that we view it on all sides as what may be seen, or felt, or smelled, or tasted? The doctor, indeed, repeatedly reprobates, as the source of much error, the notion of ideas as images in the mind; and if ideas be taken as real material figures, he is certainly in the right; but we appeal to the common sense of mankind, whether every person who distinctly conceives a triangle is not at the time conscious that his mind is affected in a similar manner, although not so forcibly, as when he actually views a triangle with his eyes? What other men may feel they know best; but we are as certain that this is the case with respect to ourselves, as we are certain of our own existence. That this affection of the mind is occasioned by some agitation in the brain, of the same kind with that which occasions actual perception, is highly probable; but whatever be the cause, the fact is undeniable.

The doctor's words, indeed, taken by themselves, would lead one to think that by conception he means in this case nothing more than the understanding of the terms of a proposition; but if that be his meaning, there was no room for controversy, as the great philosophers Cudworth, Clarke, Price, and Hume, whose opinion he is combating, would have been as ready as himself to allow, that when a man is thoroughly master of any language, he will not find any difficulty in understanding the meaning of any particular words in that language, however absurdly these words may have been put together. When Dr Price says, that "in every idea is implied the possibility of the existence of its object, nothing being clearer than that there can be no idea of impossibility, or conception of what cannot exist," his meaning evidently is, that we cannot mentally contemplate nor fancy ourselves viewing any thing corporeal, which we might not actually view with our eyes, or perceive by some other sense. This is the true meaning of conception, which is something very different indeed from understanding the separate meaning of each word contained in a proposition. Apprehension and Conception.

The learned professor, however, appeals to the practice of mathematicians for the truth of his opinion; and if they be on his side, we must give up the cause, for in no science have we such clear ideas, or such absolute certainty, as in mathematical reasoning. But it is to be observed that the word conception is not with any propriety applied to abstract truth, but to real or possible existence; nor can we be said to conceive distinctly a real or possible object, unless we are able to turn it round and round, and view it on all sides. The faculties which are conversant about abstract truth are the judgment and the reason; and truth itself consists in the agreement, as falsehood does in the disagreement, of two or more ideas or terms when compared together. If those ideas about which a judgment is to be formed can be immediately brought together, without the intervention of a third idea, it is impossible that we should judge, or, if Dr Reid will have it so, conceive that to be true which is really false. If the two ideas cannot be immediately brought together, it is impossible that we should form any judgment or conception at all about their agreement or disagreement; but we may suppose or admit, for the sake of argument, that they agree or disagree, and if that supposition conduct to a manifest absurdity, we then know that the supposition was false. It is therefore perfectly agreeable to the maxim of Price and of Hume, that mathematicians should in many cases prove some things to be possible and others impossible, which without demonstration would not have been believed; because if the ideas compared cannot be immediately brought together, no judgment, previously to the demonstration, can be formed of the truth or falsehood of the proposition; and if it concern not real or possible existence, it is a proposition with which conception has nothing to do.

"But," says Dr Reid, "it is easy to conceive, that in the infinite series of numbers and intermediate fractions, some one number, integral or fractional, may bear the same ratio to another as the side of a square bears to its diagonal." We are so far from thinking this an easy matter, that if the word *conceive* be taken in the sense in which it is used by the philosophers whose opinion he is combating, we must confess that we can form no adequate conception at all of an infinite series. When we make the trial, we can only bring ourselves to conceive the real numerical figures 1, 2, 3, &c., or the fractional parts $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, &c.; and even here our conception reaches but a small way. We have reason to believe that minds of a larger grasp can conceive at once more of the series than we can, and that the Supreme Mind conceives the whole of it, if the whole of a mathematical infinity be not a contradiction in terms; but surely no man will say that he can conceive an infinite series as he conceives a centaur, and have an adequate and distinct view of it at once. If, by conceiving that in an infinite series some one number may bear the same ratio to another that the side of a square bears to its diagonal, the doctor only means that such a supposition may be made, his observation is not to the purpose for which it is brought; for the question is not about our power to make suppositions of this kind, but about our power to raise in our imaginations an adequate and distinct mental view of possible or impossible existence. "To suppose," says Johnson, "is to advance by way of argument or illustration, without maintaining the truth of the position." In this sense a man may suppose that in an infinite series there may be some

[1] Review of the Principal Questions and Difficulties in Morals.

[2] Essays.

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one number which bears the same ratio to another that the side of a square bears to its diagonal; but such a supposition contains in it nothing that is positive, which conception always does; it is only admitting, for the sake of argument, a position, of the truth or the falsehood of which the person who makes the supposition knows nothing. He is only talking of ratios as a blind man may talk of colours. A man born blind may be made to comprehend many of the laws of optics, and may even make suppositions about colours, and reason from such suppositions to a certain extent, as clearly and justly as one who sees; but will any person say that a man blind from his birth can conceive red or green? It is much the same with respect to an infinite series. We can follow such a series so far, and may know the ratio by which it increases or decreases, and reason from what we know with the utmost certainty; but no man ever conceived the whole of an infinite series as he conceives an individual object, nor can any reasonings upon the nature of it be applied to the question of conceiving impossible existence.

But "mathematicians often require us," says Dr Reid, "to conceive things that are impossible, in order to prove them to be so. This is the case in all their demonstrations *ad absurdum*. Conceive, says Euclid, a right line drawn from one point of the circumference of a circle to another, to fall without the circle. I conceive this, I reason from it, until I come to a consequence that is manifestly absurd, and from thence conclude that the thing which I conceived is impossible." If it be indeed true that Euclid desires his readers to conceive a mathematical circle with a line drawn from one point of its circumference to another, and that line lying without the circle; if he really desires them to form such a complex conception as this, we have no hesitation in affirming that he requires them to do what is manifestly impossible. The writer of this article has not in his custody any copy of the Elements in the original Greek, and therefore cannot say with certainty what are Euclid's words; nor is it of much importance what they be; for upon a question which every man may decide for himself, by merely looking into his own mind, the authority of Euclid is nothing. The proposition to which the doctor refers is the second of the third book, and, in the edition of Simpson, is expressed thus: "If any two points be taken in the circumference of a circle, the straight line which joins them shall fall within the circle." Every mathematician who can form an adequate conception of a circle and a straight line perceives the truth of this proposition instantly, for it results necessarily from his conception; but he who has not an adequate conception of a circle may stand in need of a demonstration to show him the truth; for it is to be observed, that demonstration does not make truth, it only points it out to those who cannot perceive it intuitively, just as a microscope does not make the hairs on a mite's back, but only brings them within the field of vision.

Were a man who never examined a mite through a microscope, and who has no adequate ideas of the insect kingdom, to be asked whether there be hairs on a mite's back, he would probably answer that he did not know, but he could conceive no such hairs. In like manner, were a man who has no adequate conception of a mathematical circle, to be asked whether a straight line, which joins any two contiguous points in the circumference, could lie without the circle, he would probably answer that he did not know. Now it is to be remembered, that the reader of the Elements can have no very adequate conception of a circle when he comes to the second proposition of the third book. The definition of a circle was indeed given him in the introduction to the first book; but of that definition he has hitherto had occasion to make very little use, so that his idea of a circle will be little more accurate than that of an illiterate clown, who has no other idea of the figure than what he takes from a halfpenny or a shilling. Dr Reid himself has elsewhere[1] well observed, that "when a youth of moderate parts begins to study Euclid, every thing at first is new to him. His apprehension is unsteady; his judgment is feeble, and rests partly upon the evidence of the thing, and partly upon the authority of his teacher; but every time he goes over the definitions, the axioms, the elementary propositions, more light breaks in upon him, the language becomes familiar, and conveys clear and steady conceptions." In this state he certainly is when he reads for the first time the second proposition of the third book; his conception of a circle can then be neither clear nor steady. Our young geometrician, however, must allow, that the proposition is either true or false; and if he has read the preceding books with any advantage, he must have clear and steady conceptions of angles and triangles, and be able to demonstrate many of their properties. "Well," says Euclid, "though you have no adequate conception of a circle, you are well acquainted with plane angles and triangles, and many of their properties: Let us suppose, if that be possible, that my proposition is false, and I will show you that the supposition is absolutely inconsistent with what you know to be demonstrable or self-evident truth." This is all which Euclid can be supposed to require, when, in the words of his excellent translator, he says, "If it (the straight line) do not fall within (the circle), let it fall, if possible, without." He could not possibly desire a man who has an adequate idea of a circle, to form the positive and complex conception of that figure, with a straight line touching two points of the circumference, and yet lying on the outside of the circumference; because all his figures and lines are mere conceptions, and not real material things; and such a request would have been the same thing as if he had said, Conceive what cannot be conceived.[2]

We have insisted the longer on this point, because we think it one of the highest importance; for were it indeed true, that we could conceive impossible existence, the consequences would be very melancholy. These consequences it is needless to enumerate. Our readers will perceive, that if we could put together inconsistent ideas of sensible objects, and view them so united as one consistent whole, nothing is clearer than that our faculties would be

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[1] See Lord Kames's Sketches of the History of Man, appendix to the first Sketch on the Sciences.

[2] Principal Campbell, in treating of the commonly received doctrine of abstraction, has shown, that though Locke has in one passage of his immortal work expressed himself on the subject in terms unintelligible, his sentiments on the whole differed little from those of Berkeley and Hume: "Some," says he, "of the greatest admirers of that eminent philosopher seem to have overlooked entirely the preceding account of his sentiments on this subject; and, through I know not what passion for the paradoxical (I should rather say the impossible and unintelligible), have shown an amazing zeal for defending the propriety of the hasty expressions which appear in the passages formerly referred to. Has not the mind of man, say they, an unlimited power in moulding and combining its ideas? The mind, it must be owned, hath an unlimited power in moulding and combining its ideas. It often produces wonderful forms of its own, out of the materials originally supplied by sense; forms indeed of which there is no exemplar to be found in nature,—centaurs and griffins, 'Gorgons and hydras, and chimeras dire.' But still it must not attempt absolute impossibilities, by giving to its creature contradictory qualities. It must not attempt to conceive the same thing to be black and white at the same time; to be no more than three inches long, and yet no less than three thousand; to conceive two or more lines to be both equal and unequal; the same angle to be at once acute, obtuse, and right;" or, we may add, the two sides of a triangle to be not greater than the third. (See *Philosophy of Rhetoric*, vol. ii. p. 108. et seq.)

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contrived to deceive us, and we would be doomed to cheerless and universal scepticism.

CHAP. IV.—OF ABSTRACTION AND GENERAL IDEAS.

Every sensible object and every idea are individual.

Every sensible object is an individual, and it differs in many respects from every other object. As such it is perceived by the senses; and ideas being nothing more than relicts of sensation preserved in the imagination or memory, every idea must of course be an individual, as much as the object to which it refers. But all science, whether mathematical, moral, or metaphysical, is conversant about general truths; and if truth consist, as we have already observed, and shall more fully evince afterwards, in the agreement or coincidence of ideas, how, it may be asked, can general truth result from the comparison of particular ideas? To get rid of this difficulty, many philosophers, both ancient and modern, pretend that the mind is furnished with *general ideas*, from a comparison of which result general propositions applicable to many individuals. Philosophers, indeed, have differed in opinion respecting the source of those ideas, some of the ancients deriving them immediately from the Supreme Mind to the human, whilst almost all the moderns say that they are framed by abstraction, and therefore call them *abstract ideas*.

The doctrine of abstract ideas stated and controverted.

The doctrine of abstract ideas has been so fairly stated, and, in our opinion, so completely overturned, by Bishop Berkeley, that we shall content ourselves with abridging what he has said on the subject, and obviating some cavils which have latterly been urged against his reasoning. "It is agreed on all hands," says that learned and ingenious prelate,[1] "that the qualities or modes of things do never really exist each of them apart by itself and separated from all others; but are mixed, as it were, and blended together, several in the same object. But, we are told, the mind being able to consider each quality singly, or abstracted from those other qualities with which it is united, does by that means frame to itself abstract ideas. For example: There is perceived by sight an object extended, coloured, and moved: this mixed or compound idea, the mind resolving into its simple constituent parts, and viewing each by itself exclusive of the rest, does frame the abstract ideas of extension, colour, and motion. Not that it is possible for colour or motion to exist without extension; but only that the mind can frame to itself, by *abstraction*, the idea of colour exclusive of extension, and of motion exclusive of both colour and extension. Again, the mind having observed, that in the particular extensions perceived by sense, there is something common and alike in all, and some other things peculiar, as this or that figure or magnitude, which distinguish them from one another, it considers apart, or singles out by itself, that which is common, making thereof a most abstract idea of extension, which is neither line, surface, nor solid, nor has any figure or magnitude, but is an idea entirely prescinded from all these. So likewise the mind, by leaving out of the particular colours perceived by sense that which distinguishes them one from another, and retaining that only which is common to all, makes an idea of colour in the abstract, which is neither red, nor blue, nor white, nor any other determinate colour. And as the mind frames to itself abstract ideas of qualities or modes, so does it by the same precision or mental separation attain abstract ideas of the more compounded beings, which include several co-existent qualities. For example, the mind, having observed that Peter, James, and John, resemble each other in certain common agreements of shape and other qualities, leaves out of the complex or compounded idea it has of Peter, James, and any other particular man, that which is peculiar to each, retaining only what is common to all, and so makes an abstract idea wherein all the particulars equally partake, abstracting entirely from and cutting off all those circumstances and differences which might determine it to any particular existence. After this manner, it is said, we come by the abstract idea of man, or, if you please, humanity or human nature, in which, it is true, there is included colour, because there is no man but has some colour; but then it can be neither black nor white, nor any particular colour, because there is no one particular colour wherein all men partake. So likewise there is included stature; but then it is neither tall stature, nor low stature, nor middle stature, but something abstracted from all these; and so of the rest. Moreover, there being a great variety of other creatures that partake in some parts, but not all, of the complex idea of man, the mind, leaving out those parts which are peculiar to man, and retaining those only which are common to all the living creatures, frameth the idea of animal; which abstracts not only from all particular men, but also from all birds, beasts, fishes, and insects. The constituent parts of that abstract idea of animal are body, life, sense, and spontaneous motion. By *body* is meant body without any particular shape or figure, there being no one shape or figure common to all animals, without covering, either of hair, or feathers, or scales, &c. and yet not naked; hair, feathers, scales, and nakedness, being the distinguishing properties of particular animals, and for that reason left out of the abstract idea. Upon the same account, the spontaneous motion must be neither walking, nor flying, nor creeping: it is nevertheless motion; but what that motion is, it is not easy to conceive.

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"Whether others have this wonderful faculty of abstracting their ideas," continues the bishop, "they best can tell; for myself, I find indeed that I have a faculty of imagining or representing to myself the ideas of those particular things which I have perceived, and of variously compounding and dividing them. I can imagine a man with two heads, or the upper parts of a man joined to the body of a horse. I can consider the hand, the eye, the nose, each by itself abstracted or separated from the rest of the body. But then, whatever hand or eye I imagine, it must have some particular shape, and some particular colour. Likewise the idea of man that I frame to myself, must be either of a white, or a black, or a tawny, a straight or a crooked, a tall, or a low, or a middle-sized man. I cannot by any effort of thought conceive the abstract idea above described. To be plain, I own myself able to abstract in one sense, as when I consider some particular parts or qualities separated from others with which, though they are united in some objects, yet it is possible they may really exist without them. But I deny that I can abstract one from another, or conceive separately those qualities which it is impossible should exist so separated; or that I can frame a general notion by abstracting from particulars in the manner aforesaid; and there are grounds to think most men will acknowledge themselves to be in my case."

To think this, there are indeed such good grounds, that it is probable some of our readers, little conversant with the writings of modern metaphysicians, are by this time disposed to suspect, that the bishop, in his zeal, may have misrepresented the doctrine of abstraction; as no man in his senses, who is not perverted by some darling hypothesis, can suppose himself capable of tagging together such monstrous inconsistencies, as magnitude which is neither great nor small, and colour which is neither white, red, green, nor black, &c. But that the ingenious

[1] Introduction to the Principles of Human Knowledge.

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prelate, in his account of this process of looping and pruning, as Mr Harris contemptuously but most properly terms it, has not exaggerated in the smallest degree, is apparent from the following account of abstraction given by Mr Locke. "Abstract ideas," says that writer, "are not so obvious or easy to children, or the yet unexercised mind, as particular ones. If they seem so to grown men, it is only because by constant and familiar use they are made so; for when we nicely reflect upon them, we shall find that general ideas are fictions and contrivances of the mind, that carry difficulty with them, and do not so easily offer themselves as we are apt to imagine. For example, does it not require some pains and skill to form the general idea of a triangle (which is yet none of the most abstract, comprehensive, and difficult)? for it must be neither oblique nor rectangle, neither equilateral, equicrural, nor scalenon, but all and none of these at once. In effect, it is something imperfect that cannot exist, an idea wherein some parts of several different and inconsistent ideas are put together." "Surely," to use the words of Principal Campbell,[1] "the bare mention of this hypothesis is equivalent to a confutation of it, since it really confutes itself." But if any man has the faculty of framing in his mind such an idea of a triangle as is here described, it would be vain in us to dispute with him; for we are possessed of no such faculty, and therefore would fight on unequal terms. All we have to desire is, that the reader would fully and certainly inform himself whether he has such an idea or not; and this can be no hard task to perform. What is more easy for any one than to look a little into his own thoughts, and there try whether he has, or can attain to have, an idea of colour separated from all extension; of extension which is neither great nor small; of taste which is neither sweet, nor bitter, nor acid, nor agreeable, nor disagreeable; or the general idea of a triangle which is neither oblique nor rectangle, equicrural, equilateral, nor scalenon, but all and none of these at once?[2]

Abstract conceptions the same with abstract ideas.

Dr Reid having denied that there are or can be in the mind any ideas of sensible objects, rejects of course the doctrine of abstract general ideas, whilst he maintains in fact the very same thing, only substituting the word conception for the word idea. "What hinders me," says he, "from attending to the whiteness of the paper before me, without applying that colour to any other object?" We know nothing indeed which can hinder any man from performing this operation, which is daily and hourly performed by infants; but will the doctor say that he can attend to colour, or conceive it, abstracted from the paper and every other surface? We are persuaded that he will not, though he immediately adds, "the whiteness of this individual object is an abstract conception." Now we should rather have thought, that, consistently with his own notions of colour, he would have called the whiteness of the paper a concrete quality, and his own conception of it a particular and concrete conception. If he conceives the whiteness as separated from the paper, it is no longer the whiteness of that individual object; and he must either conceive it as abstracted from all objects, which is plainly impossible; or he must conceive it as inhering in some other object, and then neither the quality of whiteness, nor his conception of it, is abstract in general, but concrete and particular. He affirms, however, "that in abstraction, strictly so called, he can perceive nothing that is difficult either to be understood or practised." This is going much farther into the doctrine than Mr Locke went; for he owned that there was much difficulty in it. But let us see how it becomes so easy to Dr Reid. "What can be more easy," says he, "than to distinguish the different attributes which we know to belong to a subject? In a man, for instance, to distinguish his size, his complexion, his age, his fortune, his birth, his profession, and twenty other things that belong to him." All this indeed, and much more, we can do with the utmost ease; but this is not abstraction strictly so called, nor any thing like abstraction. We distinguish the size, the complexion, the age, and other attributes, of the man, from one another; but still we conceive them all as his qualities; nor is it possible, at least for us, to abstract them from him, without conceiving them as the qualities of some other man; so that our conceptions are all concrete and particular. "It ought likewise to be observed," says the professor, "that attributes may with perfect ease be distinguished and disjoined in our conception, which cannot be actually separated in the subject." They may be so in his conception, but certainly not in ours; for we can conceive nothing which may not actually exist. "Thus," continues he, "I can in a body distinguish its solidity from its extension, and its weight from both. In extension I can distinguish length, breadth, and thickness; yet none of these can be separated from the body, or from one another. It is therefore certain, that attributes which in their nature are absolutely inseparable from their subject, and from one another, may be disjoined in our conception; one cannot exist without the other, but one can be conceived without the other." So far is this from being a matter of certainty, that in every possible sense in which we can understand the word *conception*, it appears to us as evidently false as that three and two are equal to nine. It is indeed not difficult to distinguish in a body its solidity from its extension, and its weight from both; but can we distinguish them out of the body? or, to speak in plain language, can we conceive solidity as separated from all extension and all weight? Unless this can be done, and by us it cannot be done, there is no abstraction strictly so called. It is indeed easy to conceive solidity or extension abstracted from any one individual object; but how is it done? Why, by transferring your attention to some other individual object. Thus we can easily conceive solidity or extension separated from a guinea, for instance; but it is only by transferring our thoughts to another body, a piece of silver, or a ball of lead, &c. and our conceptions in both cases are particular and concrete.

As we think this opinion of Dr Reid's respecting *abstraction* both ill founded and of dangerous consequences, we have expressed our dissent from it in strong terms; and in doing so we have only followed the example set us by himself when dissenting from the theories of Hume and Berkeley. But we are so thoroughly convinced that the doctor's acuteness is superior to our own, that we are not without our fears that we may have mistaken his meaning. We are conscious that we have not wilfully misrepresented it; and to enable our readers to judge for themselves between him and us, we shall lay before them his definition of general conceptions, in his own words.

General terms.

That there are in every language general terms, is known to all mankind; for such indeed are all substantives, proper names excepted, and all adjectives. But "it is impossible," says the doctor,[3] "that words can have a general signification, unless there be conceptions in the mind of the speaker and of the hearer, of things that are general.

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[1] Philosophy of Rhetoric.

[2] "If such an extraordinary faculty (abstraction) were possible, I cannot for my part conceive what purpose it could serve. What is the use or power of that idea to which there neither is nor can be any archetype in nature, which is merely a creature of the brain, a monster that bears not the likeness of any in the universe?" (*Philosophy of Rhetoric*, vol. ii. p. 110.)

[3] Essay on the Intellectual Powers of Man.

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It is to such that I give the name of general conceptions; and it ought to be observed, that they take this denomination, not from the act of the mind in conceiving, which is an individual act, but from the object or thing conceived, which is general." Now, whatever is conceived must either be external to the mind, or present with it. But the doctor himself acknowledges, "that all the objects we perceive are individuals. Every object of sense, of memory, or of consciousness, is an individual object. All the good things we enjoy or desire, and all the evils we feel or fear, must come from individuals; and I think I may venture to say, that every creature which God has made in the heavens above, or in the earth beneath, or in the waters under the earth, is an individual." If this be so, and no man can call it in question, it is obvious that we can have no general conception of any thing external. The act of conceiving is an individual act; and therefore the only thing which can be general must be something present with the mind, and different from the mere act of conceiving. But what can this be, if not what Berkeley and others call an idea? and how can we have an idea of which we are not conscious? Yet every thing of which we are conscious, Dr Reid himself acknowledges to be an individual.

But if the doctrine generally received respecting abstract ideas be so very absurd as it has appeared in our representation, how comes it to be so prevalent amongst the most acute philosophers? To this we answer, that those philosophers have certainly in this instance been imposed upon by the structure of language. Every adjective and every substantive, proper names excepted, are words of general signification; and all science is conversant about general truth; but as words are said to be significant, not of things, but of ideas, and as truth results from the agreement or coincidence of ideas, it has been hastily supposed, that, without general ideas, there could have been neither general terms nor general truth. This is plausible, but it is not solid. Every object which affects our senses is an individual object; but we perceive that two or more objects which affect some of our senses very differently, affect others of them in precisely the same way. Thus, the paper upon which one writes, the snow which he perceives from his window, and the milk which he may use at breakfast, affect his senses of touch and taste very differently, but they present the same appearances to his eye. This diversity in the one case he believes to proceed from different powers or qualities in the several objects; and the sameness of appearance in the other, from similar qualities in these objects. To the similar qualities, though he can frame no idea of them abstracted from every individual object, he gives one common name, and calls every object which presents the same appearance to his eye that snow does, a white object; in which case the word *white* does not stand for an abstract idea, but for a quality inherent in one or more objects. Hence the origin of adjectives in language, which denote more than can be expressed by any class of substantives; for every adjective, besides the power of a name, includes in itself the force of a conjunction. (See GRAMMAR.)

The other class of general terms comprehends substantives, of which the origin is as follows. The objects about which we have occasion to speak or write are so numerous and so fluctuating, that if every individual had a proper name, a complete language could never be formed. But as there are not perhaps in nature two objects that appear to us similar in all respects, so are there not in nature two objects which affect all our senses differently. The mind, therefore, either actually perceiving two or more objects at once, or contemplating the ideas left by two or more objects in the memory, perceives, by its intellectual power, in what respects they agree and in what they disagree. If the agreement be striking, and hold in more qualities than one, it combines the several individuals into one class or species, giving to the whole a common name, which equally denotes the species and every individual belonging to it. Thus, observing that Peter, James, and John, agree in having the same erect form, in walking on two legs, in having two hands, &c., and being endowed with reason, we combine these three, and all other individuals which we perceive to agree in the same striking and important qualities, into one species, to which we give the name of *man*, a word which equally denotes the whole species and every individual of it. Again, contemplating a number of figures, which all agree in the circumstance of being bounded by three straight lines meeting one another so as to form three angles, we call the whole class of figures and each individual by the name of *triangle*, although it may be impossible to contemplate any number of triangles without perceiving that all the angles of one are acute; that one angle of another is a right angle; and that in the third there is one angle obtuse; but the word *triangle*, unless it be limited in its signification by the addition of an adjective, is equally expressive of an acute-angled triangle, a right-angled triangle, and an obtuse-angled triangle. By thus arranging individuals according to their most conspicuous qualities, we may combine all the objects existing into so many classes or species, which shall be afterwards known by as many names; but of each species we neither have nor can have any other idea than that of a multitude of similar individuals.

Classification.

As our acquaintance with nature enlarges, we discover resemblances, striking and important, between one species and another, which naturally begets the notion of a higher class called a genus. From comparing man with beasts, birds, fishes, and reptiles, we perceive that they are all alike possessed of life, or a principle of sensation and action, and of an organized body; hence we rank them all under a higher class or genus, to which we give the name of *animal*; which equally denotes the whole genus, each species comprehended under that genus, and every individual of every species. Thus, animal is a genus; man, beast, bird, are so many species comprehended under that genus; and Peter, James, and John, are individuals of the species man. Peter, James, and John, are proper names, denoting each an individual; man, beast, bird, are specific terms, denoting each a whole species, comprising many individuals; and animal is a general term, because it denotes a whole genus, comprehending under it several species, of which each consists of many individuals; and the general term denotes either the whole genus, all the species, or any individual of all the species. This is the whole mystery of abstraction; they are merely terms that in strictness of speech are general and abstract; and even these are general only as signs, of which the full signification cannot always be represented by any conceivable idea.

Names and ideas often used as mere signs.

"It is a received opinion," says Bishop Berkeley, "that language has no other end but the communicating of our ideas, and that every significant name stands for an idea. This being so; and it being withal certain, that names, which yet are not thought altogether insignificant, do not always mark out particular conceivable ideas; it is straightway concluded that they stand for abstract notions. That there are many names in use amongst speculative men, which do not always suggest to others determinate particular ideas, is what nobody will deny; and a little attention will discover, that it is not necessary, even in the strictest reasonings, that significant names, which stand for ideas, should, every time they are used, excite in the understanding the ideas they are made to stand for. In reading and discoursing, names are for the most part used as letters in algebra; in which, though a particular quan-

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tity be marked by each letter, yet, to proceed right, it is not requisite that in every step each letter suggest to our thoughts that particular quantity it was appointed to stand for." The same thing is true of ideas, which, as well as names, are often used merely as signs representing a whole class; and hence they may on that account be called general, though every idea is in itself strictly particular. Thus, "an idea, which considered in itself is particular, becomes general by being made to represent or stand for all other particular ideas of the same sort. To make this plain by example, suppose a geometrician is demonstrating the method of cutting a line in two equal parts: he draws, for instance, a black line of an inch in length; this, which in itself is a particular line, is nevertheless, with regard to its signification, general, since, as it is there used, it represents all particular lines whatsoever; and hence what is demonstrated of it is demonstrated of all lines, or, in other words, of a line in general. And as that particular line becomes general by being made a sign, so the name line, and the idea of a line in the imagination, either of which taken absolutely is particular, by being signs are made general likewise. And as the former owes its generality, not to its being the sign of an abstract or general line, but of all particular right lines that may possibly exist, so the latter, the name and the idea, must be thought to derive their generality from the same cause, namely, the various particular lines which each of them indifferently denotes." Again, when one demonstrates any proposition concerning triangles, it is to be supposed that he has in view to demonstrate an universal truth; yet the particular triangle which he considers must be either equilateral, isosceles, or scalenon; for a plain triangle, which is none of these, can neither exist nor be conceived. But whether it be of this or that sort is of no importance, as any of them may equally stand for and represent all rectilineal triangles, and on that account be denominated universal.

This doctrine generally received.

This doctrine respecting names and ideas being used merely as signs, has been adopted by almost every subsequent philosopher; and by Principal Campbell it has been illustrated with a perspicuity and acuteness every way worthy of the author of the Dissertation on Miracles. "In confirmation of this doctrine," says he,[1] "it may be observed, that we really think by signs, as well as speak by them. All the truths which constitute science, which give exercise to reason, and are discovered by philosophy, are general; all our ideas, in the strictest sense of the word, are particular. All the particular truths about which we are conversant are properly historical, and compose the furniture of memory. Nor do I include under the term historical the truths which belong to natural history, for even these too are general. Now, beyond particular truth or historical facts, first perceived and then remembered, we should never be able to proceed one single step in thinking, any more than in conversing, without the use of signs.

"When it is affirmed that the whole is equal to all its parts, there cannot be an affirmation which is more perfectly intelligible, or which commands a fuller assent. If, in order to comprehend this, I recur to ideas, all that I can do is to form a notion of some individual whole, divided into a certain number of parts of which it is constituted, suppose of the year divided into the four seasons. Now all that I can be said to discern here is the relation of equality between this particular whole and its component parts. If I recur to another example, I only perceive another particular truth. The same holds of a third and of a fourth. But so far am I, after the perception of ten thousand particular similar instances, from the discovery of the universal truth, that if the mind had not the power of considering things as signs, or particular ideas as representing an infinity of others, resembling in one circumstance though totally dissimilar in every other, I could not so much as conceive the meaning of an universal truth. Hence it is that some ideas, to adopt the expression of Berkeley, are particular in their nature, but general in their representation."

Universal propositions.

But if, in universal propositions, ideas particular in themselves be used only as the signs of others, it may be demanded, how we can know any proposition to be true of all the ideas which are represented by the sign. For example, having demonstrated that the three angles of an isosceles rectangular triangle are equal to two right ones, how can we conclude that this affection therefore agrees to all other triangles which have neither a right angle nor two equal sides? To this question Bishop Berkeley and Principal Campbell give the same answer. Although the idea we have in view whilst we make the demonstration be that of an isosceles rectangular triangle, whose sides are of a determinate length, we may yet be certain that the demonstration extends to all other rectilineal triangles, of what sort or bigness soever, for this plain reason, that neither the equality nor the determinate length of the sides, nor the right angle, are at all concerned in the demonstration. It is true, the idea or diagram we have in view includes all these particulars; but then there is not the least mention made of them in the proof of the proposition. It is not said the three angles are equal to two right angles, because one of them is a right angle, or because the sides comprehending it are of equal length; which sufficiently shows that the right angle might have been oblique and the sides unequal, and for all that the demonstration have held good. In every one of Euclid's theorems, a particular triangle, and a particular parallelogram, and a particular circle, are employed as signs to denote all triangles, all parallelograms, and all circles. When a geometrician makes a diagram with chalk upon a board, and from it demonstrates the property of a straight-lined figure, no spectator ever imagines that he is demonstrating a property of nothing else but that individual white figure, five inches long, which is before him. Every one is satisfied that he is demonstrating a property of all of that order, whether more or less extensive, of which it is both an example and a sign; all the order being understood to agree with it in certain characters, however different in other respects. Nay, what is more, the mind with the utmost facility extends or contracts the representative power of the sign as the particular occasion requires. Thus the same equilateral triangle will with equal propriety serve for the demonstration, not only of a property of all equilateral triangles, but of a property of all isosceles triangles, or even of a property of all triangles whatsoever. Nay, so perfectly is this matter understood, that if the demonstrator in any part should recur to some property belonging to the particular figure he has constructed, but not essential to the kind mentioned in the proposition, and which the particular figure is solely intended to represent, every intelligent observer would instantly detect the fallacy; so entirely for all the purposes of science does a particular serve for a whole species or genus. Now, why one visible individual should in our reasonings serve, without the smallest inconvenience, as a sign for an infinite number, and yet one conceivable individual, or a particular idea of imagination, should not be adapted to answer the same end, it will, we imagine, be utterly impossible to say.

[1] Philosophy of Rhetoric.

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Difference between ideas used as signs, and general terms.

It must, however, be confessed that there is a considerable difference in kind between ideas used as signs and the general terms of any language. Amongst all the individuals of a species, or even of the highest genus, there is still a natural connection, as they agree in the specific or generic character; and when the mind makes use of any positive idea as the sign of the species or genus, that idea appears in the imagination as an exact resemblance of some one individual. But the connection which subsists between words and things, or even between words and ideas, is in its origin arbitrary; and yet its effect upon the mind is much the same with that of the natural connection between ideas and things. For having often had occasion to observe particular words used as signs of particular things, and specific terms used as signs of a whole species, we contract a habit of associating the sign with the thing signified, insomuch that, either being presented to the mind, necessarily introduces or occasions the apprehension of the other. Custom in this instance operates precisely in the same manner as natural resemblance in the other, so that certain sounds, and the ideas of things to which they are not naturally related, come to be as thoroughly linked together in our conceptions as the ideas of things and things themselves. Nay, so completely are they linked together, that we often use, throughout long chains of reasoning, certain sounds or words, without attending at all to the ideas or notions of which they are signs. "I believe," says the author of a Treatise on Human Nature, "that every one who examines the situation of his mind in reasoning will agree with me that we do not annex distinct and complete ideas to every term we make use of; and that in talking of government, church, negociation, conquest, we seldom spread out in our minds all the simple ideas of which the compound notions signified by these terms are composed. It is, however, observable, that notwithstanding this imperfection, we may avoid talking nonsense on these subjects, and may perceive any repugnance amongst the ideas, as well as if we had a full comprehension of them." This remark generally holds true; but then it is to be observed that all the words used as signs, and which yet do not denote any one conceivable determinate idea, must be capable of definition. Thus, in matters that are perfectly familiar, in simple narration, or in moral observations on the occurrences of life, a man of common understanding may be deceived by specious falsehood, but is hardly to be gulled by downright nonsense or a repugnance of ideas. Almost all the possible applications of the terms, or, in other words, all the acquired relations of the signs, have become customary to him. The consequence is, that an unusual application of any of them is instantly detected; this detection breeds doubt; and this doubt occasions an immediate recourse to definition, which, proceeding through species and genera, resolves complex terms into others less complex, until it ends at last in simple ideas and relations, which can neither be defined nor misunderstood.[1]

It is only the power of the sign that is regarded by the mind.

Thus, then, we see, that though there are no ideas, properly speaking, general and abstract, a man may, by terms and particular ideas, used as signs, arrive at the knowledge of general truth. In neither case is it the matter, if we may be allowed the expression, but the power of the sign that is regarded by the mind. We find that, even in demonstrative reasonings, signs the most arbitrary, or mere symbols, may be used with as little danger of error as ideas or natural signs. The operations both of the algebraist and arithmetician are strictly of the nature of demonstration. The one employs as signs the letters of the alphabet, the other certain numerical characters. In neither of these arts is it necessary to form ideas of the quantities and sums signified; in some instances it is even impossible, without resolving the quantity or sum into parts, in a manner analogous to definition, and then the mind comprehends not the whole quantity or number at once, but the several parts of which it is composed, which it connects by the relation of junction or addition. Yet without this resolution the equations and calculations carried on by means of the letters and figures significant of the whole quantity or of the whole sum, are not the less accurate or convincing. And so much for abstraction, generalization, and the power of signs, whether natural or artificial.

Association of Ideas.

CHAP. V.—OF THE ASSOCIATION OF IDEAS.

A continued train of thought in the mind.

Every man whilst awake is conscious of a continued train of thought spontaneously arising in his mind and passing through it, nor could a single now or instant be pitched upon in which some idea is not present in his memory or imagination. No one idea, however, unless detained by a voluntary exertion of the mind, or unless productive of intense pleasure or pain, remains long in the imagination; but each hastens off the stage to make way for another, which takes its turn, and is succeeded by a third, &c. We are not to imagine that this train of thought is altogether fortuitous and incoherent. "It is evident," says Mr Hume,[2] "that there is a principle of connection between different thoughts or ideas of the mind, and that, in their appearance to the memory or imagination, they introduce each other with a certain degree of method and regularity. In our more serious thinking or discourse this is so observable, that any particular thought which breaks in upon the regular track or chain of ideas is immediately remarked and rejected. Even in our wildest and most wandering reveries, nay, in our very dreams, we shall find, if we reflect, that the imagination ran not altogether at adventures, but that there was still a connection upheld amongst the different ideas which succeeded each other. Were the loosest and freest conversation to be transcribed, there would immediately be observed something which connected it in all its transitions; or, where this is wanting, the person who broke the thread of discourse might still inform you, that there had secretly revolved in his mind a succession of thoughts, which had gradually led him from the subject of conversation. Amongst different languages, even where we cannot suspect the least connection or communication, it is found that words expressive of ideas the most compounded do yet nearly correspond to each other; a certain proof that the simple ideas comprehended in the compound ones were bound together by some universal principle, which had an equal influence on all mankind."

Principles of association.

That these observations are well founded, every man may be satisfied by looking attentively into his own thoughts; but when the author reduces the principles of this association of ideas to three, viz. resemblance, contiguity in time and place, and cause or effect, he certainly contracts them within too narrow a compass. That these principles often serve to connect ideas, will not indeed be denied. A picture leads our thoughts to the original; the mention of one apartment in a building introduces an inquiry or discourse concerning the others; and if we think of a wound, we can hardly forbear reflecting on the pain which follows it. But surely ideas sometimes succeed each other without resemblance, without contiguity in time or in place, and without being connected by the relation of a cause to its

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[1] For a further view of this subject, see some excellent observations on the common doctrine concerning abstraction, by Mr Dugald Stewart. (*Elements of the Philosophy of the Human Mind.*)

[2] Essays.

Association of Ideas.

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effect. Besides all this, there are other associations than those of ideas. Ideas are associated with passions and emotions, and passions and emotions are associated together. A particular idea is associated with a proper name, and often with the general name of the species. General conceptions, such as those which Mr Locke calls mixed modes, are associated with signs both audible and visible, and signs are associated with each other. Surely virtue, as it consists in action and intention, does not resemble the sound virtue, is not contiguous to it in time or in place, and is neither its cause nor its effect; nor is it conceivable that the arbitrary signs of different things should have any natural relation to one another.

But were the enumeration complete, the bare mention of these principles does not account for the phenomena; for, granting the fact, it may still be asked, why does a picture lead our thoughts to the original, or the mention of one apartment in a building introduce an inquiry concerning the others? To these questions our author has given no answer; nor are we acquainted with any writer who can be said to have attempted it, excepting Dr Hartley and his ingenious editor. There may be some of our readers whom the names of these men will prejudice against their theory; but, doubtless, the greater part are willing to adopt truth, or to examine an ingenious speculation, from whatever quarter it comes. To such as feel themselves otherwise disposed, we beg leave to say, that if they allow the name of Priestley to disgust them at what follows, they will furnish him with a new proof of the truth of the doctrine which they reject.

How they operate.

That ideas should be associated together, seems to be inevitable from the manner in which the mind acquires them. All our ideas, properly speaking, are those of sensible objects, and by far the greater part of them of visible objects. But every sensible object conveys at once various sensations and perceptions to the mind, which appear not only united in fact, but inseparable in imagination. Thus, when a man looks at any particular object, a tree, for instance, he perceives the trunk, branches, leaves, size, shape, and colour, &c. of the whole at once; he does not first perceive the figure of the trunk, then its size, then its colour, then the branches, &c. all in succession; but a perception of the whole is conveyed to the mind by one simultaneous impression. We have already seen that the senses, in fact, convey nothing to the mind but their respective sensations, and that the perception of the external object instantly follows the sensation. We have likewise seen that sensation is occasioned by some impression, concussion, or vibration, given to the nerves and brain, and by them communicated to the mind or percipient being. We have likewise seen that memory depends as much upon the brain as original sensation, and is always attended or occasioned by similar concussions or vibrations, &c. These are facts proved by universal experience, and which, we believe, no thinking man has ever called in question. It follows, therefore, that every actual sensation must leave some effect in the brain, either an actual print, which seems to be impossible, or a tendency to vibrate or be agitated in the same way as when the original impression was made. This being the case, it is natural to conclude, that when any part of the original perception is revived in the memory, the whole perception should be revived at once, so as that we cannot have an idea of the trunk of a tree without perceiving the ideas of the branches associated with it. This is indeed not merely natural, but the contrary seems to be impossible; for as the original agitation or vibration was occasioned by the whole tree, it is evident, that whatever effect or tendency that agitation or vibration left behind it, must be left by the whole vibration, and therefore be equally related to the whole tree.

But no object stands single in nature. When we view a tree, or any thing else, we always notice, however transiently, the field where it grows and the objects around it. These two leave effects in the brain at the same time that the tree does so, and therefore make their appearance with it in the memory or imagination; but if the tree was the object to which we principally attended during the actual sensation, the idea of it will be much more vivid than the idea of its adjuncts, and remain much longer in the imagination or memory; because the original sensation by which it was perceived had struck much deeper than the sensation by which its adjuncts were perceived. All this must be intelligible to every one who attends to what we have already said of sensation, perception, and memory.

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Thus we see why a picture leads our thoughts to the original, and why the mention of one apartment in a building introduces an inquiry concerning the others. It is not merely because the picture resembles the original, and because the apartments of a building are contiguous. Between a plain surface, variously coloured and shaded, and the contour of the human face, there is certainly very little real resemblance, as any man may be convinced who places his eye within six inches of a good picture. But the painter having, by his skill in perspective, contrived to lay his colours on the plain canvass in such a manner as that they reflect the same rays of light with the original, provided the spectator stand at the proper distance; these rays proceeding from the picture fall upon the eye in the same direction, and therefore give to the nerves and brain the very same impulse which was given by the original. When one apartment of a building is mentioned, we inquire concerning the others from the very same cause that, when we think of the trunk of a tree which we have seen, we cannot avoid thinking likewise of its branches.

Association gives meaning to language.

But the principle of association takes place amongst things not naturally connected, as the apartments of a building, and a substance with its attributes and adjuncts. It is association which is the original source of all the general or complex conceptions which we have, and which even gives meaning to the words of every language. Between sounds considered in themselves, and things, or the ideas of things, every one knows that there is no natural connection; yet the idea of every known object is in the mind of every man so strictly associated with the name which it bears in its native tongue, that the presence of the one always suggests the other. It cannot indeed be otherwise, if we attend to the manner in which a child learns to affix a meaning to the words which he hears. A child knows his mother and nurse, and indeed almost every visible object in the family, long before he acquires the power of articulation. The impressions made by these objects, and repeated daily and hourly on his brain, every one of which excites a sensation, must soon become so deep as not to be easily effaced. Numbers of them, too, are associated together, so that the presence of one introduces the other. It has been already observed, that ideas of sight are the most vivid and the most lasting; but the child hearing the same sound often repeated, even that sound comes in time to leave in his memory a permanent idea. He then hears the sound *nurse*, for instance, uttered at the time when he is earnestly looking at the person of the nurse, with whom he is well acquainted, and to whom he is strongly attached; and having the two ideas repeatedly excited together, they soon become so associated, that the one necessarily excites the other; the word *nurse* calls into view the idea of the woman treasured up in his imagination.

But we need not have recourse to children for the proof of our assertion. It is obvious that the name of every simple and uncompounded idea can be significant only by association. Of a complex conception the name may be made intelligible by a definition; but simple ideas cannot be defined, and between ideas and sounds there is no natu-

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ral connection, so as that the one previously to association should suggest the other. Even of complex conceptions and mixed modes, the meaning of the names is generally acquired by association; for though it is certainly true that all such names are capable of definition, they are yet used with sufficient propriety by thousands who know not what a definition is. Were a plain unlettered man asked to define virtue, it is not probable that he could do it so as to make himself understood, yet having ideas of the practice of justice, charity, fortitude, &c. strictly associated in his mind with the word *virtue*, he may understand the general meaning of that word as well as the most acute grammarian or the most profound philosopher.

An alms is a donation to a poor man; but a child who never heard of this definition knows perfectly what an alms is, from having often seen his parents give money to a beggar, and call what they were doing by the name *alms*. The sound of the word, after having seen the first alms given, will excite in his mind an idea of the individual object who received it, and of the action of him by whom it was given; but after having seen several poor men relieved, he comes to associate with the word *alms* any thing given to any person who needs it, or appears to be in want.

So completely does this association take place between ideas or clusters of ideas, and the words by which they are expressed, that even men of letters hear and understand perfectly many words, without reviewing in their minds all the ideas and relations of which they are the signs. It has been already observed, that in talking of government, church, negociation, conquest, we seldom spread out in our minds all the simple ideas of which the compound notions signified by these terms are composed; and we now add, that the terms may be used with sufficient propriety, and be perfectly understood, by those who never attempted to analyze the notions of which they are significant, into their primary and constituent parts. Every man has read numberless details of the transactions of one court with another; he has heard such transactions universally called by the term *negociation*. The term and the transactions signified by it are so closely associated in his mind, that they are in a manner inseparable, and by this association he knows the meaning of the term better than he could have done by the most complete definition, which, perhaps, he would find it difficult to give, or even to comprehend.

Source of our first notions of virtue.

We have said that the meaning of the word *virtue* is acquired by association, by having often heard that sound applied to certain actions; but it is extremely probable that the very notion of virtue, simple and uncompounded as it appears to be, is acquired in the very same manner. The first rudiments of the notions of right and wrong and obligation seem to be acquired by a child when he finds himself checked and controlled by superior power. At first he feels nothing but mere force, and consequently has no notion of any kind of restraint but that of necessity. He finds he cannot have his will, and therefore he submits. Afterwards he attends to many circumstances which distinguish the commands of a father, or of a master, from those of any other person. Notions of reverence, love, esteem, and dependence, are connected with the idea of him who gives those commands; and by degrees the child experiences the peculiar advantages of filial subjection. He sees also that all his companions who are noticed and admired by others obey their parents, and that those who are of a refractory disposition are universally disliked. These and other circumstances now begin to alter and modify the notion of mere necessity, till by degrees he considers the commands of a parent as something that must not be resisted or disputed, even though he has a power of doing it; and all these ideas coalescing, form the notions of moral right and moral obligation, which are easily transferred from the commands of a parent to those of a magistrate, of God, and of conscience. This opinion of the gradual formation of the ideas of moral right and wrong, from a great variety of elements associated together, perfectly accounts for that prodigious diversity in the sentiments of mankind respecting the objects of moral obligation; nor do we see that any other hypothesis can account for the facts. If the notion of moral obligation were a simple uncompounded idea, arising from the view of certain actions or sentiments; or were it acquired, as it certainly might be, by a chain of reasoning from the nature of God and the nature of man; why should it not in the one case be as invariable as the perception of colours or sounds, and in the other as our judgments of mathematical or physical truths? But though the shape and colour of a flower appear the same to every human eye; though every man of common understanding knows, that if a billiard ball be struck by another, it will move from its place with a velocity proportioned to the force of the impulse; and though all mankind who have but dipped into mathematics perceive that any two sides of a triangle must be greater than the third side; yet one man practises as a moral duty what another looks upon with abhorrence, and reflects on with remorse. Now, a thing that varies with education and instruction, as moral sentiments are known to do, certainly has the appearance of being generated by a series of different impressions and associations in some such manner as we have endeavoured to describe. Let not any man imagine that this account of the origin of moral sentiments endangers the cause of virtue; for whether those sentiments be instinctive or acquired, their operation is the very same, and in either case their rectitude must often be tried by the test of reason, so that the interests of virtue are equally safe on this as on any other scheme.

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It should be attended to in education.

This principle of association has so great an influence over all our actions, passions, reasonings, and judgments, that there is not perhaps any one thing which deserves more to be looked after in the education of youth. Some of our ideas, such as those of a substance and its attributes, a genus and the species contained under it, a species and its several individuals, have a real connection with each other in nature. These it is the office of our reason to trace out and to hold together in that union and order in which nature presents them to the view of the mind; for such associations constitute perhaps the greatest part of necessary and of useful truths. But there are others formed by custom and caprice, which are too often the sources of error, superstition, vice, and misery; of errors the more dangerous, and of vice the more deplorable, that if the associations have been long formed without an attempt to dissolve them, they generally become at last too strong to be broken by the most vigorous effort of the best-disposed mind. Thus, let a foolish maid[1] amuse or rather frighten children with stories of ghosts appearing in the dark, let her repeat these fictions till they have made a deep impression on the young minds, and the notion of ghosts will in time become so closely associated with the idea of darkness, that the one shall always introduce the other; and it may not be in the power of the children, after they have become men, and are convinced in their judgments of the falsehood and absurdity of the tales which originally frightened them, to eparate entirely the notion of ghosts from the idea of darkness, or with perfect ease to remain alone in a dark room. Again, let the idea of infallibility be annexed to any person or so-

[1] Locke's Essay, and his Conduct of the Understanding.

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cicty, and let these two inseparably united constantly possess the mind, and then one body in ten thousand places at once shall, unexamined, be swallowed as an incontrovertible fact, whenever that infallible person or society dictates or demands assent without inquiry.

Some such erroneous and unnatural combinations of ideas will be found to establish the irreconcileable opposition that we find between different sects in philosophy and religion; for we cannot imagine every individual of any sect to impose wilfully upon himself, and knowingly to reject truth offered by plain reason. That which leads men of sincerity and good sense blindfold, will be found, when inquired into, to be some early and erroneous association. Ideas independent and of no alliance to one another, are by education, custom, and the constant din of their party, so linked together in their minds, that they can no more be separated from each other than if they were but one idea; and they operate upon the judgment as if they really were but one. This gives sense to jargon, the force of demonstration to absurdities, and consistency to nonsense: it is the foundation of the greatest and most dangerous errors in the world; for, as far as it obtains, it hinders men from seeing and examining

The principle of association operates in the perception of external objects.

Before we dismiss the subject of association, it may be proper to inquire how far it is agreeable to the account which we have given of the manner in which external objects are perceived by means of the senses, and the ideas of such objects retained in the memory. It has been proved, we think, by arguments unanswerable, that by the organs of sense nothing is conveyed immediately to the mind but sensations which can have no resemblance to external objects, and that the perception of an object may be resolved into a process of reasoning from effects to causes. But children, it will be said, do not reason from effects to causes, and yet they soon acquire the faculty of perceiving and distinguishing the objects with which they are surrounded. This is an undoubted truth; and it can be accounted for only by the principle of association. A child has as much the use of his senses as a full-grown man. By his eye he has the sensation of colour; by his nose, that of smell; by his ear he has the sensation of sound; and by his hand he feels heat and cold, resistance and bounded resistance. Every object which is presented to him impresses his mind with various sensations; and these sensations combined together are probably all that he perceives for some years, for there is no reason to imagine that a boy of one or two years old has the slightest notion of what we mean by solidity, hardness, softness, or indeed of that which is termed *substance*. Yet when two or more objects are present, he may easily distinguish the one from the other, because the sensations excited by the one must differ from those excited by the other, as much as the real qualities of the one are different from the real qualities of the other; and by distinguishing between his own sensations, he in effect distinguishes between the objects which produce these sensations. His sensations, too, being frequently excited, leave behind them ideas in his memory or imagination; and those ideas, from having been imprinted together and never separated, become in time so closely associated, that whenever one of them is called into view, the others necessarily make their appearance with it. Thus a child has a set of combined sensations excited in his mind by the presence of his nurse; he has a different cluster excited, suppose by the presence of his mother. These are often repeated, and leave deep traces behind them, so that when the mother or the nurse makes her appearance, she is immediately recognised as a known object; or, to speak more correctly, the child feels the very same sensations which he has felt before, from which he has experienced pleasure, and of which he has the ideas treasured up in his memory or imagination. A stranger, on the other hand, must affect him with a set of new sensations, and of course will be distinguished from a known object as accurately as if the child were possessed of the notions of solidity, substance, qualities, and distance. A man born blind, who knew not that such things as fire and snow had never existed, would yet distinguish the one from the other the moment that he should be brought within their influence. He could not indeed apply their names properly, nor say which is the fire and which is the snow, nor would he at first have any notion of either of them as a real, external, and distant object; but he would certainly distinguish his own sensations, the sensation of heat from that of cold. It is just so with a child. At first he perceives nothing but different sensations. These he can distinguish; and as they are caused by different objects, in distinguishing between the sensations he will appear to distinguish between the objects themselves. In a short time, however, he acquires, by a natural process, some inaccurate notions of distance. He looks, for instance, earnestly in his nurse's face, and at the same time touches her cheek perhaps by accident. He repeats this operation frequently, till the sensation communicated by his eye comes to be associated with that of his touch, and with the extending of his arm; and being all treasured up as associated ideas in the memory, the sight of his nurse makes him ever afterwards stretch out his hands with a desire to touch her. All this while there is not the slightest probability that the child has any notion of substance or qualities, or of any thing beyond his own sensations, and the means by which he has experienced that sensations which are pleasant may be obtained, and that such as are painful may be avoided. The precise time at which a child begins to think of external things we cannot pretend to ascertain; but we are persuaded that it is later than many persons imagine, and certainly not until he has made considerable progress in the exercise of reason. Prior to that period the things which men know to be bodies, are known to children only as sensations and ideas strongly bound together by the tie of association.

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It distinguishes memory from imagination.

But if association be of such importance in the act of sensation, it is of still greater in that of retention; for it seems to constitute the whole difference that there is between imagination and memory. By many of the ancient, as well as by some modern philosophers, these two faculties seem to have been confounded with each other; but between them there is certainly a great difference, though they likewise resemble each other in some respects. An idea of memory, considered by itself, makes the very same appearance to the intellect as an idea of imagination. We contemplate both as if they were equal, though faint and distant, perceptions; but the one is attended with the conviction that it is the idea of an object which has really been perceived at some period of past time; whilst the other is attended with no conviction, except that the idea itself is actually present to the mind. Mr Hume has said that ideas of memory differ from those of imagination only in being more vivid and distinct; but certainly this is not always the case. An idea of imagination has sometimes been taken for a real perception, which an idea of memory can never be. The difference between these two kinds of ideas, we are persuaded, arises chiefly, if not wholly, from association. Every idea of memory is associated with many others, and those again with others, down to the very moment of the energy of remembrance; whereas ideas of imagination are either the voluntary creatures of the fancy at the moment of their appearance, in which case we should call them conceptions, or they are ideas which we have actually received from sensation, but which, on account of some link being broken in the vast chain of association, we cannot refer to any real objects.

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What gives probability to this conjecture is, that ideas often appear in the mind which we know not whether to refer to the memory or imagination; nothing being more common than to hear a person say, I have in my head the idea of such or such an object, but whether I remember or only imagine the object, I am very uncertain. Afterwards, however, by turning the idea over and over in the mind, he finds that other ideas make their appearance, till at last clusters of them come into view, and associate so closely with the principal idea, which was the object of doubt, as to convince the judgment that it is an idea of memory.

It is the ground of our belief of what we remember.

It has been asked, Why we believe what we distinctly remember? and to that question it has been supposed that no answer can be given. But it appears to us that association is the ground of belief in this, as it will be found to be in other instances; and that a man believes he washed his hands and face in the morning, because the idea of that operation is so strongly linked in his mind to the whole train of ideas which have arisen in it through the day, that he cannot separate the first from the last, that which was a sensation in the morning, from the sensations which are present at the instant of remembrance. As those ideas are associated by nature, each must pass in review in its proper order, so that in so short a space of time there is no danger, and hardly a possibility, of taking the first for the last, or the last for the first. Nay, more, we will venture to hazard an opinion that every past event of a man's life, which he distinctly remembers, is tied by the chain of association to his present perceptions. That this is possible is certain, since it is not difficult to conceive how it may be done. The principal events of a single day may surely be so linked together as to be all distinctly viewed in a cluster of ideas on the morrow. Of these events some one or other must be the most important, which will therefore make its appearance as an idea more frequently than the rest, and be more closely associated with the events of next day. Some event of that day will, for the same reason, be more closely associated with it than the others, and these two, dropping perhaps all the rest of their original companions, will pass on together to the third day, and so on through weeks, and months, and years. In the compass of a year, several things must occur to make deep impressions on the mind. These will at first be associated together by events of little importance, like the occurrences of a single day. Whilst these feeble chains, however, continue unbroken, they will be sufficient to link the one important event to the other, and to bring them both into view at the same time, till at last these two, from appearing so often together, will in time unite of themselves, and the intermediate ideas be completely effaced. Thus may two or three important events of one year be associated with such a number of similar events of another year, so that the ideas of the one shall always introduce to the mind the ideas of the other; and this chain of association may pass from the earliest event which we distinctly remember, through all the intermediate years of our lives, down to the instant when memory is exerted.

To this account of memory it may perhaps be objected, that it gives us no distinct notion of time. Every thing that is remembered is necessarily believed to have been present in some portion of past time; but association brings into view nothing but a series of events. This objection will be seen to have no weight when we have inquired into the nature of time, and ascertained what kind of a thing it is. It will then perhaps appear, that duration itself, as apprehended by us, is not distinguishable from a series of events; and that if there were no train of thought passing through our minds, nor any motion amongst the objects around us, time could have no existence. Meanwhile, whatever become of this opinion, we beg leave to observe, that our theory of remembrance is perfectly consistent with the commonly-received notions respecting time; and indeed that it is the only theory which can account for numberless phenomena respecting past duration. It is universally allowed, that if motion, or a succession of events, do not constitute time, it is the only thing by which time can be measured. Now it is a fact which no man will deny, that the distance of time from the present *now* or instant to the earliest period which he distinctly remembers, appears to his view extremely short, much shorter than it is said to be in reality; and that one year, when he looks forward, appears longer than two, perhaps longer than ten when he looks backward. Upon our principles this fact is easily accounted for. We remember nothing which is not linked by a chain of associations with the perceptions of the present moment; and as none but a few of the most important events of our lives can be linked together in this manner, it hence follows, that events which, in the order of succession, were far distant from one another, must thus be brought together in the memory, and the whole chain be contracted within very short limits. But when we figure to ourselves a series of future events, we employ the active power of fancy instead of the passive capacity of retention; and can therefore bring within the compass of one periodical revolution of the sun, a longer series of imaginary events succeeding each other, than is preserved of real events in our memory from the earliest period of our existence. So perfectly does our theory accord with this well-known fact. On the other hand, if memory be an original faculty of the mind, totally independent of association, and of which no other account is to be given than that it necessarily commands our belief, why is it a faculty which, with regard to duration, thus uniformly deceives us? and how comes it to pass, that to a man whose memory is tenacious, who has read much, seen many countries, and been engaged in various occurrences, any determinate portion of past time always appears longer than to another man whose memory is feeble, and whose life has been wasted in ease and idleness? To these questions we know not what answer can be given, upon any other principle than that which makes the evidence of memory depend upon association. But if we remember nothing but what is linked to the perception or idea which is present with us at the time of remembrance, and if duration be measured by the succession of events, it is obvious that any portion of past time must necessarily appear longer to him who has many ideas associated in the mind than to him who has but few.

Importance of association.

There is not perhaps a single fact of greater importance in the philosophy of the human mind than the association of ideas; which, when thoroughly understood, accounts for many of those phenomena which some distinguished writers have, with injury to science and danger to morality, attributed to a number of distinct and independent instincts. It is for this reason that we have considered it so minutely, and dwelt upon it so long; and, in addition to what we have said on the subject, we beg leave to recommend to our more philosophical readers the diligent study of Hartley's Observations on Man. In that work, we think, several things are taken for granted which require proof; and some which, we are persuaded, have no foundation in nature; but, with all its defects, it has more merit than any other treatise on the sensitive part of human nature with which we are acquainted.

Of Consciousness and Reflection.

CHAP. VI.—OF CONSCIOUSNESS AND REFLECTION.

Sensation, remembrance, simple apprehension, and conception, with every other actual energy or passion of the mind, is accompanied with an inward feeling or perception

Of Consciousness and Reflection.

Consciousness, what it is, and what are its objects.

of that energy or passion; and that feeling or perception is termed *consciousness*. Consciousness is the perception of what passes in a man's own mind at the instant of its passing there; nor can we see, hear, taste, smell, remember, apprehend, conceive, employ our faculties in any manner, enjoy any pleasure, or suffer any pain, without being conscious of what we are doing, enjoying, or suffering. Consciousness is only of things present;[1] and to apply it to things past, is to confound consciousness with memory or reflection. One cannot say that he is conscious of what he has seen or heard and now remembers; he is only conscious of the act of remembrance, which, though it respects a past event, is itself a present energy. It is likewise to be observed, that consciousness is only of things in the mind, or conscious being, and not of things external. It is improper in any person to say that he is conscious of the table before him; he perceives it, he sees it, and he may with great propriety say that he is conscious he perceives or sees it; but he cannot say that he is conscious of the table itself, for it is only his immediate energy of perception that can be the object of consciousness. All the operations of our minds are attended with consciousness, which is the only evidence that we have or can have of their existence. Should a man take it into his head to think or to say that his consciousness may deceive him, and to require a proof that it cannot, we know of no proof that can be given him; he must be left to himself as a man who denies first principles, without which there can be no reasoning. Every attempt to prove this point, or to set it in a clearer light, would only serve to render it more dark and unintelligible. I think, I feel, I exist, are first truths, and the basis of all human knowledge.

Descartes' argument for his own existence.

This has given rise to the question, whether Descartes did not fall into an absurdity when, inferring his own existence from his actual thought, he said, *Cogito, ergo sum*. This argument has been called a pitiful sophism, and a *petitio principii;* because, before a man take it for granted that he thinks, he must also, it is said, take it for granted that he exists, since there cannot be thought where there is no existence. Now it must be confessed, that if Descartes pretended by this argument to give us a fresh conviction of our own existence, his endeavours were useless and puerile; because a man capable of being convinced by the arguments of another must have a previous conviction of his own existence. But the argument itself is neither a sophism nor a *petitio principii*. Those[2] who defend Descartes assert, and there is no reason to doubt the truth of their assertion, that his only view in urging such an argument was not to prove the truth of our existence, but to exhibit the order of that process by which we arrive at the knowledge of the fact; and this he has very clearly done by analyzing the truth into its first principles. A stone exists as well as the human mind; but has the stone any knowledge of its own existence? No man will say that it has; and neither should we have any knowledge of ours, did we think as little as the stone. We certainly might exist without thinking, as it is probable that we do in very sound sleep; and in that state our existence might be known to other beings, but it could not possibly be known to ourselves; for the only things of which the mind is conscious, or has immediate knowledge, are its own operations. "I exist" is therefore a legitimate inference from the proposition "I think;" and the observation that it is so may be useful to show us the procedure of the mind in the acquisition of knowledge; but it has little merit as an argument, and still less as a discovery, though, being strictly true and just, it should never have been exposed to ridicule.

Of Consciousness and Reflection.

Reflection, what it is, and how different from consciousness.

It is to be observed, however, that we are conscious of many things to which we give very little attention. We can hardly attend to several things at the same time; and our attention is commonly employed about that which is the object of our thought, and rarely about the thought itself. It is in our power, however, when we come to the years of understanding, to give attention to our own thoughts and passions, and the various operations of our minds. And when we make these the objects of our attention, either whilst they are present, or when they are recent and fresh in our memory, we perform an act of the mind which is properly called *reflection*. This reflection ought to be distinguished from consciousness,[3] with which it is sometimes confounded by Locke, and often by the very learned author of Ancient Metaphysics. All men are conscious of the operations of their own minds at all times whilst they are awake, nor does it appear that brutes can be wholly destitute of consciousness; but there are few men who reflect upon the operations of their minds, or make them the objects of thought; and it is not probable that any species of brutes do so.

From infancy until we attain to the years of understanding, we are employed solely about sensible objects. For, although the mind is conscious of its operations, it does not attend to them; its attention is turned solely to the objects about which these operations are employed. Thus, when a man is angry, he is conscious of his passion; but his attention is turned to the person who offended him and the circumstances of the offence, whilst the passion of anger is not in the least the object of his attention. The difference between consciousness and reflection is like the difference between a superficial view of an object which presents itself to the eye, whilst we are engaged about something else, and that attentive examination which we give to an object when we are wholly employed in surveying it. It is by consciousness that we immediately acquire all the knowledge which we have of mental operations; but attentive reflection is necessary to make that knowledge accurate and distinct. Attention is a voluntary act; it requires some exertion to begin and to continue it, and by great exertion it may be sustained for a considerable time; but consciousness is involuntary, and of no continuance, changing with every thought. The power of reflection upon the operations of their own minds does not at all appear in children. Men must have come to some ripeness of understanding before they are capable of it. Of all the powers of the human mind, it appears to be the last that unfolds itself. Most men seem incapable of acquiring it in any considerable degree; and many circumstances conspire to make it to all men an exercise of difficulty. The difficulty, however, must be conquered, or no progress can be made in the science of our own or of other minds.

Our notions of mental energies.

All the notions which we have of mind and of its operations are got by reflection; and these notions are by Mr Locke termed ideas of reflection. This appellation we think extremely ill chosen; and we believe it has been the source of much error and confusion amongst Locke's followers. A man, by attending to the operations of his own mind, may have as distinct notions of remembrance, of judgment, of will, and of desire, as of any object whatever; but if the secondary perception of a sensible object, that appearance which it has to the mind when viewed in the memory or imagination, be properly called an idea, it is certain that of the operations of the mind itself there can be no ideas; for these operations, when reflected on, make no appearance without their objects, either in the memory or in the imagination. Nothing is more evident, in fact, than that we have no ideas, in the original and proper meaning of

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[1] Reid's Essays on the Intellectual Powers of Man.

[2] See Buffier's First Truth.

[3] Reid's Essays on the Intellectual Powers of Man.

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the word, but of sensible objects upon which the mind exerts its first operations. Of these operations we have indeed a consciousness; but, abstracted from their objects, we cannot frame any idea or resemblance of them. We are conscious to ourselves of thinking, willing, remembering, discerning, reasoning, judging, &c.; but let any one look into himself, and try whether he can there find any idea of thinking, or willing, &c. entirely separate and abstracted from the object of thought or will. Every man who has seen a tree or a house, will find in his mind ideas of these objects, which he can contemplate by themselves, independently of every thing else; but no man can contemplate the idea of thinking or desiring without taking into view the thing thought or desired. It is plain, therefore, that the energies of thinking, willing, and desiring, with all their various modifications, are not themselves ideas, or capable of communicating ideas to be apprehended, as the ideas of bodies are apprehended by the pure intellect. They are the actions and workings of the intellect itself upon ideas which we have received from the objects of sense, and which are treasured up in the memory or imagination for the very purpose of furnishing the intellect with materials to work upon. Between ideas and the energies of thinking there is as great and as obvious a difference as there is between a stone and the energies of him by whom it is cast. Ideas are the passive subjects; but the energies of thinking are the operations of the agents. Ideas are relicts of sensation, and have a necessary relation to things external; the energies of thinking are relicts of nothing, and they are wholly and originally internal.

Our knowledge of the operations of intellect immediate.

That we cannot in any sense of the word be said to have ideas of the operation of the intellect, will be still more evident, if we consider by what means we acquire the knowledge which we have of those operations. It has been already observed, that when our thoughts are employed upon any subject, though we are conscious of thinking, yet our attention is commonly employed upon the object of our thought, and not upon the thought itself; and that if we would give attention to our thoughts and passions, we must do it by a reflective act of the mind, whilst the act of thinking is still recent and fresh in our memory. Thus, if a man wishes to know what perception is, it is not the time to make the inquiry whilst he is looking at some rare or beautiful object; for though he is conscious of the energy of perceiving, the object of perception employs all his attention. But the time to make this inquiry is either when the object has become familiar to him, or presently after it is removed from his sight. In the former case, he can look upon it without emotion, pay attention to every step in the process of perception, and be immediately conscious what perception is. In the latter case, by turning his attention inwards, and reflecting on what he did or felt when the object was before him, he will find clear and vivid ideas of every thing which he perceived by his sense of sight; but he will find no idea of the act of seeing or perceiving. On the contrary, if he be capable of sufficient attention, he will observe that his intellect is employed in the very same manner upon the idea that it was upon the original sensations; and of that employment, and the manner of it, he will be equally conscious as he was of the original energy exerted in sensation. There is indeed this difference between the two, without which reflection could make no discoveries, that the most vivid ideas being still faint when compared with actual sensations, the intellect is not so wholly engrossed by them as it was by the original objects, nor is it so rapidly carried from idea to idea as it was from sensation to sensation. It is thus at leisure to attend to its own operations, and to know what they are; though to form ideas of them as separate from their objects is absolutely impossible. Every man capable of paying attention to what passes within himself when he sees, hears, and feels, may have very accurate notions of seeing, hearing, and feeling; but he cannot have ideas of them as he has of the objects of sight, of hearing, and of touch.

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The same is the case with respect to the exertion of our reasoning faculties. A man must have distinct and clear ideas to reason upon, but he can have no idea of reasoning itself, though he must be conscious of it, and by attention may know what it is. When a man sits down to study for the first time a proposition in the Elements of Euclid, he certainly employs his reasoning faculty, and is conscious that he is doing so; but his attention is wholly turned to the diagram before him, and to the several ideas which that diagram suggests. Afterwards, when he has mastered the proposition, he may go over it again, with a view to discover what reasoning is; but he will not find that he has any idea of reasoning as he has of the diagram. He will only exert that faculty a second time, and perceive one truth linked to and depending upon another in such a manner that the whole taken together forms a complete demonstration. In a word, the operations of our own minds, when attention is paid to them, are known immediately by consciousness; and it is as impossible that we should have ideas of them, as that a living man should be a picture upon canvass. He who attends to what passes in his own mind when he perceives, remembers, reasons, or wills, must know by consciousness what these operations are, and be capable of forming very accurate notions of them, as connected with their objects; and he who does not attend to what passes in his own mind will never acquire any notions of them, although he were to read all that has been written on the subject from the days of Pythagoras to those of Dr Reid.

There are things we know partly by sensation and partly by reflection.

As we acquire ideas of external objects by means of our senses, and notions of perceiving, remembering, reasoning, and willing, &c. by reflecting on the operations of our own minds, so there are other things of which we acquire notions, partly by sensation, partly by reflection, and partly by means of that faculty of which it is the more peculiar office to compare ideas and to perceive truth. Such are substance, body, mind, with their several qualities, adjuncts, and relations; the knowledge of which, as has been already observed, constitutes what in strictness of speech is termed the science of metaphysics. These shall be considered in order, after we have investigated the nature of truth, and inquired into the several sources of evidence; but there is one notion, about the origin and reality of which there have been so many disputes, which in itself is of so great importance, and which will be so intimately connected with all our subsequent inquiries, that it may not be improper to consider it here. The notion to which we allude is that of *power*.

Our notion of power, how acquired.

Amongst the objects around us we perceive frequent changes, and one event regularly succeeding another. Gold thrown into the fire is changed from a solid to a fluid body. Water exposed to a certain degree of cold is changed from a fluid to a solid body. Night succeeds to day, and summer succeeds to winter. We are conscious of new sensations in ourselves every hour. We are likewise conscious of reasoning, willing, and desiring; and we know that by an exertion of will we can rise or sit, stand still or walk, call one idea into view, and dismiss others from our contemplation. Experience teaches us, that it is not occasionally, but always, that gold is changed into a fluid by being thrown into the fire, and water into a solid body by being exposed to a certain degree of cold; that night succeeds to day, and summer to winter. These changes have regularly taken place since the creation of the world; and it has never once been observed that water was made solid by fire, or gold rendered liquid by cold. Were we not instructed by experience that our own voluntary motions

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are produced by exertions of our minds, of which we are conscious, and that without such exertions those motions would never have taken place, we should probably have considered the liquefaction of gold as an event equally independent of fire, though uniformly conjoined with it, as night is independent of day, and day of night. But having experienced that we can move or not move our bodies as we please, that when it is our will to sit we never get up to walk, and that when we wish to walk we always do it except prevented by external violence; having likewise experienced that by a thought, by some internal and inexplicable exertion of our minds, we can call up in our memory or imagination one idea, and dismiss others from our mental view; we are led to believe with the fullest conviction, that all those motions of our bodies which in common language are termed voluntary, and that succession of ideas which follows a conscious exertion of the mind, depend entirely upon ourselves. In other words, we are necessitated to believe that we have a power to move or not to move our bodies in many cases, and a power to turn our attention to one idea in preference to others.

It is in this way that we acquire the notion of power in ourselves, which we easily transfer to other objects. Knowing that the various motions of our bodies thus effected proceed from power, we are naturally led to inquire whether the changes which we perceive in other bodies may not proceed from power likewise, or from something analogous to that power, of the exertions of which we are conscious in ourselves. Now uniform experience teaching us that gold is liquefied by being thrown into the fire, and that water is made solid by being exposed to cold, we infer with the utmost certainty that there are powers in fire and cold to produce these changes, and that without the exertion of such powers these changes would not be produced. We cannot indeed say of external powers, as we can of our own, in what substance they inhere. We know with the utmost certainty that the voluntary motions of our hands, &c. are produced by a power not inherent in the hands, but in the mind, for of the exertion of that power we are conscious; but we do not know whether the power which liquefies gold be inherent in that sensible object which we call fire, or in something else to which fire is only an instrument. We learn by observation, that the minute particles of fire or heat insinuate themselves between the particles of gold, and, if we may use the expression, tear them asunder; but whether they do this in consequence of a power inherent in themselves, or only as instruments impelled by another power, is a question which observation cannot enable us to answer.

Were we not conscious of the exertion of our own powers, it seems scarcely conceivable that we could ever have acquired any notion of power at all; for power is not an object of sense, nor, independent of its operations, is it indeed an object of consciousness. In external operations, all that we perceive is one thing, in which we suppose the power to reside, followed by another, which is either the change or that on which the change is produced; but the exertion of the power itself we do not perceive. Thus we perceive gold, after it has been some time in the fire, converted from a solid to a fluid body; but we perceive not by our senses either the power or the energy of the power which operates to this conversion. In the exercise of our own powers, the case is otherwise. When a man puts his hand to his head, and afterwards thrusts it into his bosom, he not only perceives by his senses the change of position, but he is also conscious of the energy or exertion by which the change was produced.

Doctrine of Mr Hume.

"Suppose," says Mr Hume, "a person, though endowed with the strongest faculties of reason and reflection, to be brought on a sudden into this world, he would indeed immediately observe a continual succession of objects, and one event following another, but he would not be able to discover any thing farther. He would not at first by any reasoning be able to reach the idea of cause and effect, since the particular powers by which all natural operations are performed never appear to the senses. The impulse of one billiard ball is attended with motion in the second. This is the whole that appears to the outward senses. The mind feels no sentiment or inward impression from this succession of objects; consequently there is not, in any single particular instance of cause and effect, any thing which can suggest the idea of power or necessary connection. From the first appearance of an object, we never can conjecture what effect will result from it; but, were the power or energy of any cause discoverable by the mind, we could foresee the effect, even without experience, and might at first pronounce with certainty concerning it by the mere dint of thought and reasoning. It is impossible, therefore, that the idea of power can be derived from the contemplation of bodies in single instances of their operations; because no bodies ever discover any power which can be the original of this idea."

There is a sense in which this reasoning is unquestionably just. A man who had never been conscious of exerting power in himself would certainly not acquire the notion of power from observing a continual succession of external objects. The impulse of one billiard ball being followed by the motion of another, would no more lead him to the notion of power in the former than the succession of night to day would lead him to the notion of a power in light to produce darkness. When Mr Hume says, "that, from the first appearance of an object, we can never conjecture what effect will result from it," he uses language that is ambiguous, and utters an assertion which is either true or false according to the sense in which it is understood. If it be meant, that after having reflected upon the operations of our own minds, and learned by experience that motion is communicated by impulse from one ball of ivory to another, we could not conjecture whether a similar effect would be produced by the impulse of balls made of other hard bodies which we had never before seen, the assertion is manifestly false. A man who had but once seen motion communicated in this manner from one ivory ball to another, would certainly conjecture that it might be communicated from one wooden ball to another; and if he had observed it repeatedly communicated from one ball to another of different substances, he would infer, with the utmost confidence, that it might be communicated from ball to ball, of whatever substance composed, provided that substance be hard, or of a similar texture with the balls to the impulse of which he had formerly paid attention. If by this ambiguous phrase the author only means, as is probably the case, that from the first appearance of an object to which we had never before observed any thing in any respect similar, we could not conjecture what effect would result from it; or if his meaning be, that a man suddenly brought into the world, who had never acquired such a notion of power as may be had from attention to the energies and operations of our own minds, would not, by observing an effect to result from one body, conjecture from the first appearance of another similar body what effect would result from it;—in either of these cases his assertion is certainly true, and tends to prove, that without the consciousness of the operations of our own minds, we could never acquire a notion of power from the changes perceived by our senses in external objects.

His attempt to prove that we have no notion of power.

But Mr Hume, not contented with denying, which he might justly do, that we could ever have derived the idea of power merely from observing the continual succession of external objects, labours hard to prove that we have no notion of power at all, and that when we employ the word

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power, we do nothing more than utter an insignificant sound. To pave the way for the arguments by which so extravagant a paradox is to be supported, he lays it down as a "proposition which will not admit of much dispute, that all our ideas are nothing but copies of our impressions; or, in other words, that it is impossible for us to think of any thing that we have not antecedently felt either by our external or internal senses." As this proposition, however, will, it seems, admit of some dispute, he takes care, before applying it to the purpose of demolishing all power, to support it by two arguments. "First," says he, "when we analyze our thoughts or ideas, however compounded or sublime, we always find that they resolve themselves into such simple ideas as were copied from a precedent feeling or sentiment. Those who would assert that this position is not universally true nor without exception, have only one, and that an easy method of refuting it, by producing that idea, which, in their opinion, is not derived from this source. Secondly, if it happen, from a defect of the organ, that a man is not susceptible of any species of sensation, we always find that he is as little susceptible of the correspondent ideas. A blind man can form no notion of colours, a deaf man of sounds. And though there are few or no instances of a like deficiency in the mind, where a person has never felt, or is wholly incapable of a sentiment or passion that belongs to his species, yet we find the same observation to take place in a less degree. A man of mild manners can form no idea of inveterate revenge or cruelty; nor can a selfish heart easily conceive the heights of friendship and generosity."

His reasoning sophistical.

As these propositions are the engines by which all power is banished from the world, it may not be improper, before we proceed to inquire by what means they perform so arduous a task, to consider their own inherent strength; for if they be weak in themselves, their work, however dexterously they may be employed, can have no stability. We have already noticed the perverseness of this writer's language, when it confounds sensations with impressions; but here it is still more perverse, for passions, sentiments, and even consciousness, are styled impressions. When sensations are confounded with impressions, the effect is only mistaken for the cause, it being universally known that sensations proceed from impressions made upon the organs of sense. When consciousness is confounded with an impression, one thing is mistaken for another, to which it is universally known to have neither resemblance nor relation. But, not to waste time upon these fallacies, which, though dangerous if admitted, are yet too palpable to impose upon a reader capable of the slightest attention, let us examine the propositions themselves. The most important, and that for the sake of which alone the others are brought forward, is, "that it is impossible for us to think of any thing that we have not antecedently felt, either by our external or internal senses." Did Mr Hume, then, never think of a mathematical point, or a mathematical line? Neither of these things is capable of being felt, either by making an impression upon the organs of sense or as an object of consciousness, and therefore it is impossible that he should ever have had ideas of them such as he doubtless had of sensible objects; yet in the most proper sense of the word *think*, he certainly thought of both points and lines; for he appears to have made considerable progress in the science of geometry, in which he could not have proceeded a single step without a perfect knowledge of these things, on which the whole science is built. It is not therefore true, that our thoughts or ideas, when analyzed, always resolve themselves into such simple ideas as were copied from a precedent feeling or sentiment; for every mathematical figure of which we can think resolves itself into a point and motion; and a point having no parts and no magnitude, cannot possibly be the object of feeling to any of our senses.

If, therefore, ideas alone be the objects of thought, we have refuted Mr Hume's position by the very method which he himself lays down; for we have produced an idea which is not derived either from a precedent feeling or a precedent sentiment. By sentiment, we suppose to be here meant that which by other philosophers is denominated consciousness; and of consciousness it is undeniable that nothing is the object but the actual energies of our own minds.

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Things of which we cannot have ideas may be the objects of thought.

But ideas are not the only objects of thought. We have already given our reasons for restricting the word *idea* to that appearance which an object of sense, when reflected on, makes, either in the memory or imagination. Such was undoubtedly its original signification; and had it never been used to denote other and very different objects, much error and perplexity would have been avoided, which now disgrace the science of metaphysics. Things may themselves be the objects of thought; and when that is the case, to think of their ideas, were it possible to do so, would be worse than useless; for we may certainly know a man better by looking at himself than by looking at his picture. Of things which are themselves the objects of thought, we have either a direct or a relative knowledge. We know directly the actual operations of our own minds by the most complete of all evidence, that of consciousness; and we have a relative notion of mathematical points and lines, but neither of mental energies nor of these external things can we possibly have any idea.

We can reason about things of which we have only relative notions.

It is well observed by Dr Reid, that our notions both of body and of mind are nothing more than relative. "What is body? It is, say philosophers, that which is extended, solid, and divisible. Says the querist, I do not ask what the properties of the body are, but what is the thing itself? let me first know directly what body is, and then consider its properties. To this demand I am afraid the querist will meet with no satisfactory answer; because our notion of body is not direct, but relative to its qualities. We know that it is something extended, solid, and divisible, and we know no more. Again, if it should be asked, what is mind? It is that which thinks. I ask not what it does, or what its properties are, but what it is. To this I can find no answer; our notion of mind being not direct, but relative to its operations, as our notion of body is relative to its qualities." (*Essay on the Active Powers of Man.*)

Our notion of a mathematical point is of the very same kind. What is a point? It is, says Euclid, that which has no parts and no magnitude. Replies the querist, I ask not either what it has or what it has not; let me first know what it is. To this second question, it might perhaps be answered, that a mathematical point is that which by motion generates a line. But, rejoins the querist, I am not inquiring what it generates; give me a direct idea of the point itself; or, if that cannot be done, as assuredly it cannot, tell me what its offspring a line is. A line, says Euclid, is length without breadth. I have no idea, replies the querist, of length without breadth. I never felt an impression from a sensible object which did not suggest length, breadth, and thickness, as inseparably united; and I can have no idea which is not the copy of a former impression. To assist the querist's conception, it may be said that lines are the boundaries of a superficies, and that superficies are the boundaries of a solid body; and of a solid body every man has a clear and direct idea, in the most proper sense of the word. Here then are several things, namely, points, lines, and superficies, of not one of which is it possible to form a direct notion; and yet we know them so thoroughly, from the relation which they bear to other subjects, that we can reason about them with a precision and certainty which the mathematical sciences alone admit of.

The great advantage of these sciences above the moral Mr Hume himself expressly admits; but he attributes it

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Such is the notion of power.

to a wrong cause when he says it consists in this, that the "ideas of the former being sensible, are always clear and determinate;" for we see that the notion of a point or of a line is merely relative, and cannot possibly be the copy of a sensation, or, in his language, of a sensible impression. If, then, we have clear and determinate notions of points and lines, and may reason about them without ambiguity, as he acknowledges we may, what is there to hinder us from having an equally clear and determinate notion of power, or from reasoning about it with as little ambiguity?[1] Why, says he, we are not conscious of power. And to prove this position, which needs no proof, he makes many observations that, however just, might certainly have been spared. Of these, one is not a little curious. "A man suddenly struck with a palsy in the leg or arm," says he, "or who has now lost these members, frequently endeavours at first to move them, and employ them in their usual offices. Here he is as much conscious of power to command such limbs, as a man in perfect health is conscious of power to actuate any member which remains in its natural state and condition. But consciousness never deceives. Consequently, neither in the one case nor in the other are we ever conscious of any power." This is true; we are never conscious of any power; but we are frequently conscious of actual energies; and the man who, after being suddenly struck with a palsy, endeavours in vain to move his leg or arm, is as conscious of energy as he who in health makes the same attempt with success. Nor let it be imagined that his consciousness deceives him; for, as Mr Hume justly observes, consciousness never deceives. He is certain of the energy, but finds by experience that the instrument of this energy has suddenly become disordered and unfit for its usual office. In this and this alone consists the difference between the paralytic and the man whose limbs are sound. The one may be as conscious of energy as the other, and his consciousness may be equally infallible. But what then is this energy? Mr Hume will not say that it is an idea, for it is not the copy of any antecedent impression; besides, he has somewhere allowed that ideas are never active. Is it then a substance? Impossible, for it is not permanent; and we believe no man will venture to affirm, or even to suppose, that the same substance can be repeatedly annihilated, and as often created. Is it, then, the occasional exertion of some substance? This must be the truth, for no other supposition remains to be made. If so, that substance must be possessed of power; for a capacity of exerting actual energy is all that is meant by the word power. "Wherever there is a capability of energy or exertion, there must be power; for though there can be no exertion without power, there may be power that is not exreted. Thus a man may have power to speak when he is silent; and he may have power to rise and walk when he sits still. But though it be one thing to speak and another to have the power of speaking, we always conceive of the power as something which has a certain relation to the effect; and of every power we form our notion by the effect which it is capable of producing. Nor is it only in speaking and moving his limbs that a man is conscious of energy. There is as much energy, though of a different kind, in thinking as in acting. Hence the powers of the human mind have been divided into active and speculative. By the former we move the body; and by the latter we see, hear, remember, distinguish, judge, reason, and perform upon our notions and ideas every other operation which is comprehended under the general word *to think*."[2]

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Locke's passive power an improper expression.

Mr Locke[3] has introduced into his theory of power another distinction than that which we have here made between active and speculative powers. Observing by our senses, under which on this occasion memory is certainly included, various changes in objects, we collect, says he, a possibility in one object to be changed, and in another a possibility of making that change, and so come by that idea which we call power. Thus we say that fire has a power to melt gold, and that gold has a power to be melted. The first he calls active, the second passive power. But to say that the possibility of being changed is power, seems to be a very improper mode of speaking, and such as may lead to consequences which the excellent author certainly held in abhorrence. It tends to make unwary readers imagine that the passive subject is as necessary to the existence of power as the active being of which power is an attribute; but if the universe had a beginning, and if its Creator be immutable, two propositions which Mr Locke firmly believed, there certainly was power when there was no change, nor any thing existing which was capable of change. He owns, indeed, that active power is more properly called power than the other; but we see no propriety at all in what he calls passive power. "It is," in the language of Dr Reid, "a powerless power, and a contradiction in terms."

Observations of the same author respecting power.

But although Locke here uses improper terms, he makes some other observations with which we have the honour fully to agree, and which lead to consequences the reverse of that impiety which seems to follow from the notion of passive power. He observes, that "we have from body no idea at all of thinking, nor any idea of the beginning of motion. A body at rest affords us no idea of any active power to move; and when it is set in motion itself, that motion is rather a passion than an action in it. For when the ball obeys the stroke of a billiard stick, it is not any action of the ball, but a passion; also, when by impulse it sets another ball in motion that lay in its way, it only communicates the motion it had received from another, and loses in itself so much as the other received, which gives us but a very obscure idea of an active power moving in body, whilst we observe it only to transfer, but not to produce, any motion. So that it seems to me, we have from the observation of the operation of bodies by our senses, but a very imperfect, obscure idea of active power, since they afford us not any idea in themselves of the power to begin any action either of motion or thought." He thinks

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[1] "There are some things of which we can have both a direct and relative conception. I can directly conceive ten thousand men, or ten thousand pounds, because both are objects of sense, and may be seen. But whether I see such an object, or directly conceive it, my notion of it is indistinct; it is only that of a great multitude of men, or of a great heap of money; and a small addition or diminution makes no perceptible change in the notion I form in this way. But I can form a relative notion of the same number of men or of pounds by attending to the relations which this number has to other numbers greater or less. Then I perceive that the relative notion is distinct and scientific; for the addition of a single man, or a single pound, or even of a penny, is easily perceived. In like manner, I can form a direct notion of a polygon of a thousand equal sides and equal angles. This direct notion cannot be more distinct when conceived in the mind, than that which I get by sight when the object is before me; and I find it so indistinct that it has the same appearance to my eye, or to my *direct* conception, as a polygon of a thousand and one, or of nine hundred and ninety-nine sides. But when I form a *relative* conception of it, by attending to the relation it bears to polygons of a greater or less number of sides, my notion of it becomes distinct and scientific, and I can demonstrate the properties by which it is distinguished from all other polygons. From these instances it appears, that our relative conceptions of things are not always less distinct, nor less fit materials for accurate reasoning, than those that are direct; and that the contrary may happen in a remarkable degree." (Reid's *Essays on the Active Powers of Man.*)

[2] Reid's Essays on the Active Powers of Man.

[3] Essay, book ii. chap. xxi.

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it evident, however, "that we find in ourselves a power to begin or forbear, continue or end, several actions of our minds and motions of our bodies, barely by a thought or preference of the mind ordering, or, as it were, commanding, the doing or not doing such or such a particular action. This power which the mind has thus to order the consideration of any idea, or the forbearing to consider it, or to prefer the motion of any part of the body to its rest, and *vice versa*, in any particular instance, is that which we call will. The actual exercise of that power, by directing any particular action, or its forbearance, is that which we call volition or willing."

Such beings only as have will and understanding can possess real power.

According to Mr Locke, therefore, the only clear notion or idea we have of power is taken from the power which we find in ourselves to give certain motions to our bodies, or certain directions to our thoughts; and this power in ourselves can be brought into action only by willing or volition. This is exactly our doctrine, where we have endeavoured to prove, that without the consciousness of actual energy in ourselves, we never could have acquired any notion at all of power from observing the changes which take place amongst external objects. But if this be so; if the power, of which alone we know any thing, can be brought into action only by willing or volition; and if will necessarily implies some degree of understanding, as in us it certainly does; it comes to be a question of the first importance, whether any being which possesses not will and understanding can be possessed of real power, or be the efficient cause of any action. This question we feel ourselves compelled to answer in the negative. If we had not will, and that degree of understanding which will necessarily implies, it is evident that we could exert no power, and consequently could have none; for power that cannot be exerted is no power. It follows also, that the power, of which alone we can have any distinct notion, can be only in beings who have understanding and will. Power to produce any effect, implies power not to produce it; and we can conceive no way in which power may be determined to one of these rather than the other in a being who has not will. We grow from infancy to manhood; we digest our food, our blood circulates, our heart and arteries beat; we are sometimes sick and sometimes in health; all these things must be effected by the power of some agent, but they are not done by our power. And if it be asked how we know this, the obvious answer is, because they are not subject to our will. This is the infallible criterion by which we distinguish what is our doing from what is not, what is in our power from what is not. Human power can be exerted only by will; and we are unable to conceive any active power to be exerted without will. If, therefore, any man affirms that a being may be the efficient cause of an action which that being can neither conceive nor will, he speaks a language which we do not understand. If he has any meaning, he must take the words *power* and *efficiency* in a sense very different from ours; for the only distinct notion, indeed the only notion, which we can form, of real efficiency, is a relation between the cause and effect similar to that between us and our voluntary actions. It seems, therefore, most probable that such beings only as have some degree of understanding and will can possess active power, and that inanimate beings must be merely passive. Nothing which we perceive without us affords any good ground for ascribing active power to any inanimate being; and we can as little conceive such a being possessed of power, as we can conceive it capable of feeling pain. On the other hand, every thing which we discover in our own constitution leads us to think that active power cannot be exerted without will and intelligence; and to affirm that it can, is to affirm what, to us at least, is a contradiction in terms.

To this reasoning, which is Dr Reid's, and which to us appears to be unanswerable, we have heard it objected, that a man born blind has the same evidence for the non-existence of colour that is here urged for the impossibility of power being exerted without will and understanding. If the objection had not been made by a very acute man, we should have deemed it altogether unworthy of notice; for between the two cases supposed to be similar there is hardly any analogy. A man born blind has no notion whatever of colour. If you describe it to him in the best manner you can, and refer it to any of the senses which he possesses; if you say that it is the object of feeling, and that by feeling it one may perceive things at the distance of many miles; the blind man has reason to say that you are uttering a proposition which he knows with the utmost certainty cannot possibly be true. But if you tell him that colour is the object of the sense of sight, a sense which he possesses not; that it has not the least resemblance to the objects of the other senses; and that persons endowed with the sense of sight perceive coloured objects at the distance of many miles; the blind man cannot know whether what you say be true or false, because he has no idea or conception of the things of which you speak. This is not the case with respect to power; for every man who has reflected on the operations of his own mind has a very distinct notion of power, and knows perfectly, that to the actual exertion of the only power which he can conceive, will and understanding are necessary. Should it be said that there may be power altogether different from that of which we have a distinct conception, we think it sufficient to reply, that of a thing which cannot be conceived, nothing can be either affirmed or denied; that activity exerted without will and understanding ought not to be called an exertion of power, because power is the name already appropriated to the attribute of a being, by which he can do certain things if he wills; that as we cannot form any notion of a real efficient cause which has not will and understanding, so we have no reason to believe that such a cause anywhere exists; and to say that power, such as we can conceive, may be exerted without will and understanding, is as great an absurdity as to say that there may be velocity without space.

Of Truth. An objection obviated.

But if active power, in its proper meaning, requires a subject endowed with will and intelligence, what shall we say of those active powers which philosophers teach us to ascribe to matter, the powers of corpuscular attraction, magnetism, electricity, gravitation, and others? These powers, as they are called, shall be considered when we come to treat of the nature and source of corporeal motion. In the mean time, it is sufficient to observe, that whatever may be the agents in the operations of nature, whatever the manner of their agency or the extent of their power, they depend upon the First Cause, and are all under his supreme control.

CHAP. VII.—OF TRUTH AND THE DIFFERENT SOURCES OF EVIDENCE.

SECT. I.—*Of Truth.*

By pursuing these inquiries in the order which to us appears most natural, we are now led to the contemplation of those faculties of the human mind of which truth is properly the object. But what is truth? This was a famous question amongst the Greek sophists, which had been so often agitated, and to which so many absurd answers had been given, that it came at last to be doubted by men of the world whether a satisfactory answer could be given to it, or indeed whether the matter was worthy of investigation. It is well known, that amongst the ancient philosophers there was a sect called from their principles Sceptics, and

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from their founder Pyrrhonists, who openly avowed their opinion that truth, like virtue, is nothing but a name;—that all things are equally true, or rather equally doubtful;—and that it is in vain for man to hope for certainty in any inquiry in which he can be engaged. Such scepticism as this no modern philosopher has professed; but many have had enough of it to make sober men hesitate about defining truth, and even insinuate that of truth no definition can be given. This, however, is surely a mistake. If truth cannot be defined, it still wanders at large and in disguise, and vain must be the pursuit of every man who endeavours to obtain it, for he is pursuing he knows not what.

Truth defined.

So obvious and so solid is this reflection, that almost every philosopher of merit who has latterly written on the nature of evidence, has begun his work, if not with a formal definition, with something at least equivalent to a definition, of the object of his pursuit. To repeat all these definitions could serve no other purpose than to swell this article to a disproportioned bulk, and to perplex perhaps the mind of the reader. We shall therefore content ourselves with that which is given by Mr Wollaston. "Those propositions," says he, "are true which represent things as they are, or truth is the conformity of those words or signs by which things are expressed to the things themselves." Notwithstanding the objections of Dr Tatham, the acute author of the Chart and Scale of Truth, this is the best definition of truth which we have yet met with in any language. It is concise and perspicuous. It comprehends all kinds of truth, as well that which is merely mental, the subject of silent contemplation, as that which is communicated either by written language or by the living voice; and it makes truth itself immutable, as depending, not upon the arbitrary constitution of this or that individual, or even of the whole human race,[1] but upon the nature of things as established by the Almighty Creator of all.

Every proposition is either true or false.

According to this definition, every proposition which can be expressed or apprehended is necessarily either true or false, whether its truth or falsehood be perceived or not, either by him who hears or by him who utters it. All propositions are either affirmative or negative; but before any thing can with certainty be affirmed or denied of another, we must know those things as they are in themselves, as well as the established use of the signs by which they are expressed. He who affirms or denies without this knowledge, speaks at random, and has no distinct meaning.

Every faculty concerned in the acquisition of truth.

Every faculty which we possess is in some way or other an instrument of knowledge; for we know by our senses, by our memory, and by our intellect. Every one of our faculties, therefore, is concerned in the acquisition of truth, and furnishes the mind with the materials of propositions. These propositions are indeed of various kinds; but they are all certainly true or certainly false, though the certainty of the truth or falsehood of every one it is not always in our power to perceive.

When a man affirms that red is a quality inherent in a soldier's coat, he utters a proposition which every one of the vulgar firmly believes to be true, but which every philosopher knows to be false. This diversity of belief, however, does not affect the truth of the proposition itself. All mankind know that it is either true or false, independently of them or their perceptions; and it is easy, by a few optical experiments, and by an explanation of terms, to convince them all, that what they have agreed to call red is no quality inherent in external objects, but only a sensation caused by the impulse of certain rays of light reflected from certain objects to the eye of the percipient. The contrariety, therefore, in this case of vulgar to philosophical belief, does not result from any ambiguity in the nature of truth itself, but from the different means of perception which the clown and the philosopher possess.

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Diversity of belief affects not the truth of what is believed.

Again, were a man looking at a red and a green object, to affirm that they are both of the same colour, he would affirm what in one sense may be true, what in another is undoubtedly false, and what in a third may be either true or false. If it be his meaning that the two objects give to him the same sensation, he may know with the utmost certainty that what he says is true; if he mean that they affect all mankind precisely as they affect him, he utters what all mankind with the most absolute certainty know to be false; if he mean that the texture of the two bodies (that particular disposition of parts on their surfaces which makes them reflect certain rays of light and absorb others) is exactly similar, so that the one must reflect the very same kind of rays with the other, he utters what all mankind must believe to be false, although still it is possible that what he affirms may be true. This diversity of belief affects not the truth itself. The two objects are what they are, by whomsoever perceived, or whether perceived or not. The rays of light reflected by each are what they are, whether they fall upon this, upon that, or upon any other eye; and the sensation communicated to this singular man is certainly what he is conscious it is, as those of the rest of mankind are with equal certainty what they are conscious of. This being the case, it is obvious and undeniable, that the organs of sight in this individual of the human race are somehow differently formed from those of other men; and the only question which can occasion a doubt in the mind of the sceptic is, whether his or their eyes be so formed as to represent things falsely; for that by the one or the other things are falsely represented, is as evident as that two contradictory propositions cannot both be true. Now, although for any thing we know it is certainly possible, as to us it appears not to imply any contradiction, that the eyes of but one man are formed in a manner suitable to their objects, whilst the eyes of all other men are formed to deceive them; yet the contrary is so highly probable, that no man really doubts of it, any more than he doubts whether three and two be equal to five.

Why some truths are absolutely, and others morally certain.

This last proposition is indeed said to express a truth absolutely certain, whilst the former expresses a truth which is called morally certain; not that there is any difference or degrees of certainty in the nature of truths themselves; the only difference consists in our power of

[1] Dr Beattie, in his Essay, has given a definition of truth very different from this, though it is possible that his meaning may be the same with Mr Wollaston's. "I account that to be truth," says he, "which the constitution of our nature determines us to believe, and that to be falsehood which the constitution of our nature determines us to disbelieve." But if truth be really immutable, as he teaches or wishes to teach, it must depend upon the nature of things, and not upon the instinctive impulse of any particular constitution. It is always difficult, often impossible, to distinguish between the constitution of our nature as it came from the hand of God, and the same constitution as it is moulded by arbitrary and capricious associations of our own. A sincere member of the church of Rome certainly believes the doctrine of transubstantiation. How he may do so we have already shown. Were all mankind sincere members of that church, it would be said and thought, "that the constitution of human nature determines men to believe transubstantiation;" a doctrine which, though it is rejected by millions, Père Buffier has laboured hard to reconcile with common sense. Yet it is certain that the same body cannot be in different places at the same time; and that therefore transubstantiation must be false, although believed by all mankind. Our believing any thing does not make it true, nor our disbelieving any thing make it false. We must, indeed, act according to our belief; but in every instance truth and falsehood would have been what they are although we had never existed.

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perceiving them. That three and two are equal to five is said to be an absolute truth, because we perceive the whole of it as it is in itself, and are convinced that every intelligence, from the highest to the lowest, who understands the terms in which it is expressed, perceives it as we do; whereas of moral or of physical truths, as they are called, we only perceive a part, and may therefore mistake for want of evidence. Thus, in the case of the two objects exhibiting the same colour to one man, whilst they exhibit different colours to all other men, could we see into the objects themselves, and comprehend them immediately with our intellect as we comprehend our own ideas, it might, and no doubt would, appear as palpable a contradiction to say that the particular disposition of the parts on the surfaces, which reflect the rays of light, are the same in both, as it is now to affirm that three and two are not equal to five. Between truth and falsehood there is no medium. All truths are in themselves equally certain; and to the Supreme Being, who knows the nature of every thing more fully and intimately than we know our own ideas, they must all appear equally certain; but yet we may without absurdity speak of probable truth as well as of certain truth, provided always that we make the difference to result, not from the nature of things, but from the power of our understanding, which comprehends the one kind of truth wholly and the other only partially.

Some truths eternal and necessary, others temporary and contingent.

There is another division made of truth into that which is eternal and necessary, and that which is temporary and contingent. Though we do not approve of applying the epithets temporary and eternal to any thing but real existences, yet as this manner of speaking has been used by all philosophers, we shall give instances of each kind of truth, and endeavour to ascertain in what the distinction consists. "The three angles of a plain triangle are equal to two right angles," is a proposition expressive of a necessary and eternal truth. "The world exists," is a contingent and temporary truth. Here it is very obvious, that if both these propositions be true, there is no distinction between them, so far as mere truth is concerned; for truth admits not of degrees of comparison. It is however said, that the first proposition depends not upon time, nor will, nor any thing else, and that the Supreme Being himself could not make it false: whereas it is certainly possible, that he who created the world could annihilate it, and thus reduce what is now a truth to an absolute falsehood. This difference between the two propositions is thought a sufficient ground for calling the former a necessary and eternal truth, and the latter a temporary and contingent truth. But is the difference itself real? In the present instance we cannot think that it is; for if the right angles and triangles, which constitute the materials of the former proposition, be real corporeal things, they may be annihilated as well as the rest of the world; and then the truth of the proposition will cease, for there can be neither equality nor inequality between nonentities. If the angles and triangles be merely ideas in the mind of a rational being, it is not to be denied that the proposition must be true, independently of all will, whenever those ideas exist, or whenever right angles and triangles are thought upon; but if all reasonable creatures were to be annihilated, and the Supreme Being never to think of triangles, the proposition would unquestionably cease to be either true or false. The world may indeed be annihilated; but it certainly is not annihilated whilst any one creature exists to contemplate even that which is called necessary and eternal truth; and therefore, whilst any truth exists in a mind not divine, it must be necessarily true that the world exists; for the individual being by which truth is perceived would then constitute the whole world.

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But if in a somewhat different manner we compare the former of these propositions with this, "The solar system consists of the sun and at least seven primary planets," we shall at once perceive the difference between necessary and contingent truths. Both propositions we know to be true at this moment; but there is this difference between them, that a plain triangle can neither actually exist at any period of duration, nor be conceived by any one mind, divine nor human, of which the three internal angles are not precisely equal to two right angles; whereas the solar system may easily be conceived, and might certainly have been formed, with a smaller number of primary planets rolling round the central orb. This needs no proof, as it is well known that till very lately we conceived the system to consist of the sun and only six primary planets; and it has been already shown, that whatever we can positively conceive may possibly exist. Thus, then, every proposition, of which the contrary is clearly and distinctly perceived to be impossible, is a necessary truth; and it may likewise be said to be eternal, because at every period of duration it must of necessity when thought upon be perceived to be true. On the other hand, every proposition of which the contrary may be clearly and distinctly conceived, is, if true, only a contingent truth, because its contrary might have existed; and it may likewise be called temporary, because what might have been false in time past may yet be false in time to come.

Truth perceived by the rational faculties.

Though all our faculties, our senses, our memory, and our intellect, furnish materials for propositions, and are therefore all subservient to the investigation of truth, yet the perception of truth, as it is in itself, is commonly ascribed to our rational faculties; and these have by Locke and others been reduced to two, namely, reason and judgment. The former is said to be conversant about certain truths, the latter chiefly about probabilities.

Common sense.

Some modern philosophers of great merit, dissatisfied with this analysis of the intellect, have added to reason and judgment a third faculty, to which they have given the name of *common sense*, and of which the proper object is such truths as neither admit nor stand in need of evidence. By common sense they mean "that degree of judgment which is common to men with whom we can converse and transact business." Whether the introduction of such a term into metaphysics was proper or improper, we do not think it of importance to inquire. According to this definition of it, which is Dr Reid's, it differs not from the reason and judgment of Locke;[1] agreeing with the former

[1] This is expressly acknowledged by Dr Reid. "It is absurd," says he, "to conceive that there can be any opposition between reason and common sense. It is indeed the first-born of reason; and as they are commonly joined together in speech and in writing, they are inseparable in their nature. We ascribe to reason two offices or two degrees: the first is to judge of things self-evident; the second to draw conclusions that are not self-evident from those that are. The first of these is the province, and the sole province, of common sense; and therefore it coincides with reason in its whole extent, and is only another name for one branch or one degree of reason." Père Buffier talks nearly the same language; but Dr Beattie expresses himself very differently. "That there is a real and essential difference between these two faculties; that common sense cannot be accounted for by being called the perfection of reason, nor reason by being resolved into common sense; will appear," he thinks, "from the following remarks: 1. We are conscious, from internal feeling, that the energy of understanding which perceives intuitive truth, is different from that other energy which unites a conclusion with a first principle by a gradual chain of intermediate relations. 2. We cannot discern any necessary connection between reason and common sense." Nay, he says that "we often find men endued with the one who are destitute of the other:" and he instances dreams and certain kinds of madness where this is the case; adding, "that a man who believes himself made of glass, shall yet reason very justly concerning the means of preserving his supposed brittleness from flaws and fractures."

Of Intuitive Evidence and Demonstration.

when its object is certain truth, and with the latter when it is conversant about probabilities. Nothing indeed is more evident, than that, in the assent of the mind to every proposition, some energy of the judgment is exerted; and upon every proposition not self-evident, reasoning of some kind or other must be employed to procure that assent. Instead therefore of perplexing ourselves and our readers with various analyses of the human understanding, or rather with various names to what after all is perhaps but one individual power, it will surely be of more importance to the cause of truth to examine the different sources of evidence by which the assent of the reason, or judgment, or common sense, is determined.

Sect. II.—*Of Intuitive Evidence and Demonstration.*

Intuitive evidence.

Intuitive evidence is that which arises from the comparison of two or more ideas or notions when their agreement or disagreement is perceived immediately, without the intervention of any third idea or notion. Of this kind is the evidence of these propositions: One and four make five;[1] things equal to the same thing are equal to one another; the whole is greater than any of its parts; and, in a word, all the axioms in arithmetic and geometry. All these are in reality propositions in which the subject and predicate appear upon comparison to be nothing more than the same thing taken in different views, or expressed by different terms. In fact, they are all in some respect reducible to this axiom: "Whatever is, is." We do not say that they are deduced from it; for they have in themselves that original and intrinsic evidence which makes them, as soon as the terms are understood, to be perceived intuitively. And if they be not thus perceived, no deduction of reason will ever confer on them any additional evidence. But although not deduced from the general axiom, they may be considered as particular exemplifications of it; inasmuch as they are all implied in this, that the properties and relations of our clear and adequate ideas can be no other than what the mind clearly perceives them to be.

Every demonstration is a series of propositions intuitively evident.

It may perhaps be thought that if axioms were propositions perfectly identical, it would be impossible by their means to advance a single step beyond the simple ideas first perceived by the mind. And it would indeed be true, that if the predicate of the proposition were nothing but a repetition of the subject under the same aspect, and in the same or synonymous terms, no conceivable advantage could be made of it for the furtherance of knowledge. Of such propositions as these, for instance, "Seven are seven, eight are eight, the three angles of a triangle are the three angles of a triangle, two right angles are two right angles," it is manifest that we could never avail ourselves for the improvement of science. But when the thing, although in effect coinciding, is considered under a different aspect; when that which is single in the subject is divided in the predicate, and conversely; or when what is a whole in the one is regarded as a part of something else in the other; such propositions lead to the discovery of innumerable and apparently remote relations. It is by the aid of such simple and elementary principles that the arithmetician and the algebraist proceed to the most astonishing discoveries. Nor are the operations of the geometrician essentially different; for to this class belong all propositions relating to number and quantity; that is, all which admit of mathematical demonstration. If the truth of a mathematical proposition be not self-evident; in other words, if the subject and predicate do not appear at first sight to be different names for the same thing; another term must be found which shall be synonymous to them both. Thus, to prove that the three internal angles of a right-lined triangle are equal to two right angles, I produce the base of the triangle; and by a very short process I discover that the exterior angle, so formed, is equal to the two interior and opposite angles. By a process equally plain and short, I perceive that the exterior angle and the interior adjacent angle are equal to two right angles. But I have already seen, that the exterior angle is neither more nor less than the two interior and opposite angles under a different aspect; whence it appears that the three internal angles of the triangle are nothing else than two right angles under a different aspect. In a word, all demonstration is founded on first principles or primary truths, which neither admit nor stand in need of proof, and to which the mind is compelled to give its assent by a bare intuition of the ideas or terms of which these primary truths are composed. Nothing is susceptible of demonstration, in the rigid sense of the word, but general, necessary, and eternal truths; and every demonstration is built upon intuition, and consists in a series of axioms or propositions of the very same kind with the first principle or truth from which the reasoning proceeds. That propositions formerly demonstrated are taken into the series, does not in the least invalidate this account; inasmuch as these propositions are all resolvable into axioms, and are admitted as links in the chain; not because they are necessary, but merely to avoid the useless prolixity which frequent and tedious repetitions of proofs formerly given would occasion. But it is obvious that such truths only as result from the comparison of ideas and notions are necessary, and of course that such truths only are capable of strict demonstration. The truths which relate to real existences are all contingent, except that which affirms the existence of the Supreme Being, the parent of all truth.

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The mathematical sciences, categorical logic, and that part of metaphysics which demonstrates the being of God, are therefore the only branches of human knowledge which admit of strict demonstration. The longest demonstration in the mathematical sciences may be traced to this general and necessary truth, "Whatever is, is," or to some particular exemplification of it: the longest train of categorical syllogisms terminates in this general principle, "What is affirmed or denied of a whole genus, may be affirmed or denied of all the species, and all the individuals belonging to that genus:" and the metaphysical demonstration of the being of God rests upon this foundation, "Whatever had a beginning must have had a cause." That these are truths absolutely certain, which can neither be proved nor called in question, every man may be satisfied, merely by attending to the ideas or notions which the terms of each proposition express. The two first are merely identical propositions, of the truth of which no man has ever pretended to doubt; and though the last is not identical, it is a necessary and self-evident truth, as its contrary implies, that in the same thing there is power and no power, change and no change, action and inaction, at the same instant of time.

By intuition we acquire our notions of relation.

Before we dismiss the subject of intuition, it may not be improper to observe, that it is by this faculty or power of the mind contemplating its ideas and comparing one idea with another, that we acquire all our notions of relation; such as identity and diversity, resemblance, co-existence, relations of space and time, relations of quantity and number, of a cause to its effect, and many more which it would be useless as well as tedious to enumerate.

Sect. III.—*Of Experience and Analogy.*

It has been just observed, that intuition and demonstration are applicable only to general and necessary pro-

[1] Campbell's Philosophy of Rhetoric.

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positions, of which the contrary are not only false, but absurd and impossible. The great business of life, however, is with facts and contingent truths, which admit not of demonstration, but rest upon other evidence. The senses, external and internal, are the inlets to all our knowledge of facts; and the memory is the storehouse where that knowledge is preserved. Of what a man sees or feels, he can at the instant of seeing or of feeling entertain no doubt; and whilst the ideas of what he has seen or felt, with all their associated circumstances, remain vivid and distinct in his memory, he is conscious that he possesses so much real knowledge. But all our knowledge, as it is derived from the senses, is of particular facts or particular truths; and the man who has in certain circumstances observed one particular phenomenon, for the existence of which he perceives no necessity, has not sufficient ground to conclude, that in similar circumstances similar phenomena will always occur. Milton, who surpassed the greater part of his contemporaries in philosophical science almost as far as he has surpassed all succeeding poets in the sublimity of his genius, represents Adam, when first falling asleep, as under apprehensions that he was about to sink into his original state of insensibility.

Experience the result of repeated observations.

> Gentle sleep
> First found me, and with soft oppression seiz'd
> My droused sense, untroubled; though I thought
> I then was passing to my former state
> Insensible, and forthwith to dissolve.

Apprehensions similar to these would take place in his mind when he first perceived that darkness had overspread the earth. In his circumstances, he could have no ground to expect that the sun when once set would rise again to re-illumine the world, as he had not then experienced the alternate succession of light and darkness, and probably knew not whence light proceeded. After some time, however, having observed day and night regularly to succeed each other, these two appearances, or the ideas of them, would be so associated in his mind, that each setting sun would suggest the idea of next sunrising, and lead him to expect that glorious event with the utmost confidence. He would then consider the alternate succession of day and night as a law of nature, which might be affirmed in a proposition expressive of a certain truth.

Experience the only evidence we have for the truths in physics.

This continued observation of the same event happening in the same or similar circumstances is what we call experience; and it is the only evidence which we have for all the general truths in physics, even for those which we are apt to think intuitively certain.[1] Thus, that milk is white, and that gold is yellow, are supposed to be universal and necessary truths; but, for any thing that we know, they may be particular truths; and they are certainly contingent, as the contrary to either of them may be supposed without absurdity. We have indeed always observed that the milk of animals of every species is white; and therefore the idea of whiteness becomes a necessary part of our idea of the substance milk, of which we call whiteness an essential property. This, however, respects only the milk of those animals with which we are acquainted. But since the milk of all the animals with which we are acquainted, or of which we have heard, is white, we can have no reason to suspect that the milk of any new and strange animal is of any other colour. Also, since, wherever there has been the specific gravity, ductility, and other properties of gold, the colour has always been yellow, we conclude that these circumstances are necessarily united, although by some unknown bond of union, and that they will always go together.

The proper proof, therefore, of such universal propositions as that "milk is white," that "gold is yellow," or that "a certain degree of cold will freeze water," consists in what is called an induction of particular facts of precisely the same nature. Having found, by much and various experience, that the same events never fail to take place in the same circumstances, the expectation of the same consequences from the same previous circumstances is necessarily generated in our minds; and we can have no more suspicion of a different event than we can separate the idea of whiteness from that of the other properties of milk. When the previous circumstances are precisely the same, we call the process of proof by the name of induction, and expect the event from experience; but if they be not precisely the same, but only bear a considerable resemblance to the circumstances from which any particular appearance has been found to result, we call the argument analogy; and it is stronger in proportion to the degree of resemblance in the previous circumstances. Thus the milk of all the cows that we have seen, or upon which we have made the experiment, having been found nutritious, we confidently expect that the milk of all other cows will prove nourishing likewise; and this confidence of expectation is the result of uniform experience. But if, from having found the milk of all the animals with which we are acquainted to be nourishing, however different the nature of these animals, we infer that the milk of any strange animal will likewise be nourishing, the inference is drawn by analogy, and by no means carries with it the conviction of experience. A proof from real experience can leave no doubt in the mind; an argument from analogy always must. In the one case, we only infer that two events of precisely the same nature, and in precisely the same circumstances, have been produced by the same kind of cause; in the other, we infer that two events similar in most respects, although, for any thing that we know, dissimilar in others, have been produced by the same kind of cause; and it is obvious that between these cases the difference is great.

Of Experience and Analogy.

Difference between experience and analogy.

Thus, after having observed that all the projectiles to which we have paid any attention, a stone thrown from the hand, a ball from a gun, and an arrow from a bow, describe a certain curve, and are impelled in that curve by two powers acting in different lines of direction, which form with each other a certain angle, we infer that all projectiles which on the surface of the earth describe the same curve, are impelled by the same or by similar powers acting in the same or similar lines of direction. This inference is the result of experience, and carries with it the fullest conviction to the mind. But when, from having observed that the curves described by the planets are of the same kind with those described by projectiles on the earth, Sir Isaac Newton inferred that these vast bodies are impelled in their orbits by forces of the very same kind, and acting in the same manner, with the forces which impel a ball from a cannon or an arrow from a bow, his argument was founded only on analogy, and even that analogy was very remote. We know by experience that all projectiles which fall under our immediate cognizance are of the very same kind and in the very same circumstances; that every one of them has a tendency, from whatever cause, to the centre of the earth, and is preserved from falling by the force of projection. We know likewise that they are all moved through the medium of the atmosphere, which at the surface of the earth is considerably dense, and that a dense medium must occasion much resistance. But we do not know that the planets have a tendency to the centre of the sun, that they are preserved from falling into that luminary by a projectile force, or whether they move through a medium or *in*

The evidence of analogy inferior to that of experience.

[1] Campbell's Philosophy of Rhetoric, and Priestley's Remarks on the Drs Reid, &c.

Of Testimony.

vacuo; so that we are not certain that the motion of the planets is perfectly similar to that of terrestrial projectiles in any other circumstance than the form of the curve which they all describe; and from this single case of coincidence no inference can be drawn which carries to the mind absolute conviction.

When a man reasons from experience, he infers, that what has uniformly happened hitherto, will happen always in the very same circumstances; or that what is known to be the cause of various phenomena of the same kind is the cause of every other phenomenon in all respects similar to these. Such an inference is founded on the united and complete evidence of sense, memory, and reason. When a man reasons from analogy, he infers, that what has generally happened hitherto, will happen again in circumstances nearly similar; or that what is known to be the cause of various phenomena of the same kind, is the cause of other phenomena in some respects similar to these. This inference is likewise founded on the united evidence of sense, memory, and reason; but here the evidence of sense is not complete, and it can be strengthened only by finding more facts of the same or of a similar nature.

Sect. IV.—*Of Testimony.*

Mankind ready to believe the testimony of each other.

The last source of evidence which we proposed to consider is testimony, or the report of men concerning events which have fallen under the observation of their senses. That we are all ready to believe the information which we receive from the testimony of our fellow-creatures, is undeniable; and indeed, without such belief, every man's knowledge of facts and events would be confined to those only of which he himself had been a personal witness. In that case, no man who had not travelled would believe that there are such cities as Rome and Constantinople; and no man whatever could now believe that such heroes as Hannibal and Cæsar had ever existed.

Between words and things there is no natural connection; and although we are all accustomed to give to things the names by which they are known in the language that we speak, and to express their mutual relations by the words appropriated for that purpose, yet it is obviously impossible to denote one thing by the name of another, and to express by words relations which have no existence. This being the case, it may be asked, upon what principle do we give credit to human testimony? To this question various answers have been given, which have produced much controversy on one of the most important subjects which can employ the mind of man.

Reason assigned by Hume for this propensity.

"We may observe," says Mr Hume,[1] "that there is no species of reasoning more common, more useful, and even necessary to human life, than that which is derived from the testimony of men and the reports of eye-witnesses and spectators. This species of reasoning perhaps one may deny to be founded on the relation of cause and effect. I shall not dispute about a word. It will be sufficient to observe, that our assurance in any argument of this kind is derived from no other principle than our observation of the veracity of human testimony, and of the usual conformity of facts to the reports of witnesses. It being a general maxim that no objects have any discoverable connection together, and that all the inferences which we can draw from one to another are founded merely on our experience of their constant and regular conjunction, it is evident that we ought not to make an exception to this maxim in favour of human testimony, whose connection with any event seems in itself as little necessary as any other. Were not the memory tenacious to a certain degree; had not men commonly an inclination to truth, and a principle of probity; were they not sensible to shame when detected in falsehood; were not these, I say, discovered by experience to be qualities inherent in human nature, we should never repose the least confidence in human testimony. And as the evidence derived from witnesses and human testimony is founded on past experience, so it varies with that experience, and is regarded either as a proof or probability, according as the conjunction between any particular kind of report and any kind of object has been found to be constant or variable. There are a number of circumstances to be taken into consideration in all judgments of this kind; and the ultimate standard by which we determine all disputes that may arise concerning them, is always derived from experience and observation. The reason why we place any credit in witnesses and historians, is not derived from any connection which we perceive *a priori* between testimony and reality, but because we are accustomed to find a conformity between them. But when the fact attested is such a one as has seldom fallen under our observation, here is a contest of two opposite experiences, of which the one destroys the other as far as it goes, and the superior can only operate on the mind by the force which remains. The very same principle of experience which gives us a certain degree of assurance in the testimony of witnesses, gives us also, in this case, another degree of assurance against the fact which they endeavour to establish; from which contradiction there necessarily arises a counterpoise, and mutual destruction of belief and authority."

Of Testimony.

This account of the origin of our faith in testimony has been controverted with much success by the Doctors Campbell and Reid. "That the evidence of testimony is derived solely from experience," says the former of these writers,[2] "is at least not so incontestable a truth as Mr Hume supposes it; that, on the contrary, testimony hath a natural and original influence on belief antecedent to experience, will, I imagine, easily be conceived. For this purpose, let it be remarked, that the earliest assent which is given to testimony by children, and which is previous to all experience, is, in fact, the most unlimited; that by a gradual experience of mankind, it is gradually contracted, and reduced to narrower bounds. To say, therefore, that our diffidence in testimony is the result of experience, is more philosophical, because more consonant to truth, than to say that our faith in testimony has this foundation. Accordingly, youth, which is unexperienced, is credulous; age, on the contrary, is distrustful. Exactly the reverse would be the case were this author's doctrine just." This is a complete confutation of the reasoning of Mr Hume; but in order to prevent all cavilling, it is to be wished that the very acute author had explained more fully what he means by saying that testimony has a natural and original influence on belief; for these words may be taken in different senses, in one of which what he affirms is true, and in another it is false.

Dr Campbell's omission is amply supplied by Dr Reid, who gives the following account of testimony, and of the credit which it obtains. "The wise and beneficent Author of nature, who intended that we should be social creatures, and that we should receive the greatest and most important part of our knowledge by the information of others, hath, for these purposes, implanted in our nature two principles that tally with each other. The first of these principles is a propensity to speak truth, and to use the signs of language so as to convey our real sentiments. This principle has a powerful operation even in the greatest liars; for where they lie once, they speak truth a hundred

[1] Essay on Miracles.

[2] Dissertation on Miracles, and The Philosophy of Rhetoric.

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times. Truth is always uppermost, and is the natural issue of the mind. It requires no art or training, no inducement or temptation, but only that we yield to a natural impulse. Lying, on the contrary, is doing violence to our nature, and is never practised, even by the worst men, without some temptation. Speaking truth is like using our natural food, which we would do from appetite, although it answered no end; but lying is like taking physic, which is nauseous to the taste, and which no man takes but for some end which he cannot otherwise attain. When we are influenced by any motive, we must be conscious of that influence, and capable of perceiving it upon reflection. Now, when I reflect upon my actions most attentively, I am not conscious that in speaking truth I am influenced on ordinary occasions by any motive moral or political. I find that truth is always at the door of my lips, and goes forth spontaneously, if not held back. It requires neither good nor bad intention to bring it forth, but only that I be artless and undesigning. There may indeed be temptations to falsehood, which would be too strong for the natural principle of veracity, unaided by principles of honour or virtue; but where there is no such temptation, we speak truth by instinct. By this instinct, a real connection is formed between our words and our thoughts; and thereby the former become fit to be signs of the latter, which they could not otherwise be." (*Inquiry into the Human Mind.*)

Such is the account which Dr Reid gives of the truth of human testimony; and he adds, that there is another original principle implanted in us by the Supreme Being, to tally with it, viz. a disposition to confide in the veracity of others, and to believe what they tell us. "This," he says, "is the counterpart to the former; and as that may be called the principle of veracity, we shall, for the want of a more proper name, call this the principle of credulity. It is unlimited in children until they meet with instances of deceit and falsehood; and retains a very considerable degree of strength through life."

It is ever with extreme reluctance that we controvert the opinions of this able writer; and that reluctance cannot be lessened in the present instance, when we are conscious that great part of what he says is unanswerable. That truth is always at the door of the lips; that it requires no effort to bring it forth; that in ordinary cases men speak truth uninfluenced by any motive moral or political; that the greatest liars speak truth a hundred times where they lie once; and that lying is never practised by the worst men without some temptation; are positions which daily experience renders it impossible to question. But, notwithstanding this, we do not think that truth is spoken by an instinctive principle; because it is inconceivable that instinct should teach the use of arbitrary and artificial signs, such as the words of every language undoubtedly are; or that between such signs and ideas any instinctive connection should ever be formed. "Truth," as we have defined it, "is the conformity of those words or signs by which things are expressed, to the things themselves;" and things themselves are what they are, independently of us, our instincts, and perceptions. When we have precise and adequate ideas of objects, and when those ideas are related to one another as the objects themselves are related, we are in possession of mental truth; and in this case there is a real and natural connection between the signs and the things signified. For we cannot frame original and simple ideas which have no archetype in nature; nor can one object, distinctively perceived, generate in our minds the ideas that are generated by other objects. Here external things are the objects, and ideas are the signs, which, when they are in conformity to the things signified by them, constitute truth.

But, in human testimony, the ideas in the mind of the speaker are the things signified, and the words of language are signs by which they are expressed; and when these things and signs are in conformity to each other, the words uttered express so much truth. Now, though in this case there is no natural connection between the sign and the thing signified, yet it is obvious, that without a violent effort of the speaker to the contrary, they must always be in conformity with each other; because in every language there are words appropriated for the purpose of denoting every idea and relation which can be expressed; and in the mind of every man these ideas, relations, and words, have been constantly associated, from the time that he learned to speak. So intimate is this association, and so impossible to be broken, that whoever will pay sufficient attention to the operations of his own mind, will find that he thinks as well as speaks in some language; and that in cogitation he supposes and runs over, silently and habitually, those sounds which in speaking he actually utters. If this be so, it is impossible that a man without some effort should ever speak any thing but truth: for the ideas of what he has seen or heard, &c. are not of his manufacture; they are generated by external objects, and, till they be effaced from the memory, they must always, by the law of association, make their appearance there, with all their mutual relations, and in their proper dress. In the very act of learning to speak, we necessarily learn to speak the truth; for were we not to employ words exactly as they are employed by those with whom we converse, our language, if language it might be called, would be unintelligible; and we could neither declare our wants nor ask relief with any hopes of success. Children beginning to speak may indeed utter untruths without any motive, and merely from mistake, because the ideas and words of children have neither been long nor closely associated; but it is impossible that a man, however wicked, should habitually and without motives lie on ordinary occasions, unless the fundamental principles of his nature have been totally altered; unless his brain has been disordered by disease; unless his ideas have been disarranged, and all his original associations broken.

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The true reason assigned.

We know indeed by woful experience, that immoral men occasionally utter falsehoods with a view to deceive. But on these occasions they are influenced by some motive either of hope or terror. The falsehood is always uttered with an effort; and so strong is the association between words and ideas, that the truth will at times break out in spite of all their endeavours to suppress it; so that the end or middle of a false narrative, if it be of any length, is commonly inconsistent with the beginning. We entertain a suspicion concerning any matter of fact, when those who relate it contradict each other; when they are but few in number, or of a doubtful character; when they have an interest in what they affirm; when they deliver their testimony with hesitation, or, on the contrary, with too violent asseverations; because these are circumstances which we have generally experienced to accompany false evidence. It is likewise with reluctance that we admit a narrative of events entirely different from every thing which hitherto we have seen or heard; because we may not be certain that the narrator is not under some influence to deceive us in matters concerning which we have nothing but his testimony upon which to ground our judgment. But in every case where the fact recorded is in itself possible, and attributed to an adequate cause; where a competent number of witnesses had sufficient means of information, and are certainly under no inducement to deceive, testimony is complete evidence, however extraordinary the fact may be; because no fact which is known to have an adequate cause can be so incredible, as that a number of men of sound understandings should act contrary to the fundamental principles of human nature, or

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be able, if so disposed, to dissolve associations which had been formed in the mind of each from his infancy, and to form new ones, all agreeing exactly with one another, but all contrary to truth.

PART II.

OF BODY WITH ITS ADJUNCTS.

CHAP. I.—OF THE COMPOSITION OF BODIES; OR, OF MATTER AND FORM.

Hitherto we have contemplated only the powers of our minds by which we acquire a stock of ideas, and the various operations of the intellect upon those ideas, as treasured up in the memory or imagination. In the course of the inquiry we have found, that every idea and notion which we have was suggested by something independent of us; and in order to discover what those things are, we have investigated the nature of each sense, as it is by the senses only that we have any communication with the external world. By touch we perceive heat and cold, hardness and softness, figure and solidity, motion and extension; by the organ of smell we perceive odours; by the tongue and palate, tastes; by the ear, sounds; and by the sight, colours. We have likewise seen, that heat and cold, odours, tastes, sounds, and colours, are mere sensations, which have no existence but whilst they are perceived. On the other hand, hardness and softness, figure and solidity, motion and extension, are neither sensations, nor like sensations; but are conceived to be something external and independent of our faculties, which may operate in a desert wilderness as well as in a populous city; although, for want of sentient beings to operate upon, it cannot in the wilderness produce the same effects as in the city.

Of things perceived by the senses, the greater part are always united.

Of things perceived by the senses we find the greater part always united; for when a man perceives a piece of sealing-wax, if he makes use of all his senses, he perceives at once cold, taste, colour, hardness, roughness or smoothness, figure, solidity, motion or rest, and extension. That the powers or qualities which in this instance produce the sensations of heat or cold, taste, odour, and colour, are so united to the hardness, figure, solidity, and extension of the wax, that they cannot exist alone, is very evident; because it is impossible to remove any one of these things, or to conceive it removed, without removing with it all the rest. What then is the bond of this union? Do these things necessarily accompany one another, so that one of them cannot exist without bringing all the rest along with it? No. There is no necessary connection amongst them; for by the operation of fire the wax may be rendered liquid, when the hardness and cold are gone, although every thing else remains the same, or nearly the same, as it was before. By a still further operation of fire the appearance may be entirely changed; and that which was formerly a piece of hard red wax, may be reduced to smoke and ashes, in which there is neither hardness, colour, odour, nor figure; at least there is not in the smoke and the ashes such hardness, colour, odour, or figure, as was in the wax. The solidity and extension, however, remain; for we perceive ashes and smoke to be extended and solid, as much as wax or adamant; nor is it possible to do any thing with the wax, or with any other sensible object, which shall deprive it of extension or solidity.

Some of these things termed accidents.

Thus, then, extension and solidity may exist and be perceived, when separated from hardness, colour, and odour; but none of these can exist, nor be conceived to exist, independently of extension and solidity. Hardness, colour, odour, taste, and figure, or the things which suggest these notions to us, have with great propriety been termed accidents or qualities; because they cannot exist nor be conceived to exist by themselves, but require for their support one common subject. Extension and solidity can exist independently of them, but they cannot exist independently of solidity and extension.

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Qualities which inhere in a subject called matter.

Is then solidity the basis of these qualities, so that they necessarily result from it? No. There are many things solid and extended which are neither hard, nor coloured, nor odorous, nor sapid; which could not be if these qualities were the necessary effect of solidity. Besides, all mankind conceive of solidity and extension as qualities of something else; for we never say that solidity is extended or coloured, or hard or odorous, but that something solid has these qualities; and hence it is evident that we consider solidity as a quality itself. In what, then, does solidity and all the other sensible qualities inhere, since they cannot exist separately, and do not support each other? This is a question which modern philosophers do not pretend to answer. But some of the ancients were not so modest. Aristotle and his followers resolved every bodily substance into matter and form; making matter the basis or substratum, and under form comprehending all sensible qualities.

As attempts have latterly been made to revive this philosophy, it may not be improper to give a short view of the doctrine of matter and form, if it were only to discover whether the speculations of Aristotle and his adherents on this subject deserve to be preferred to those of Newton and Locke.

The Peripatetic doctrine concerning matter.

The most perspicuous, and by far the most elegant writer, among the moderns, who has adopted the ancient philosophy, is Mr Harris; and, lest we should be accused by others of doing injustice to a subject above the reach of ordinary comprehension, we shall transcribe so much of what he has said of matter and form in his Philosophical Arrangements as seems necessary to make our readers understand his meaning, as far as it is intelligible. "Matter," says this writer, "is that elementary constituent in composite substances which appertains in common to them all, without distinguishing them from one another. Every thing generated or made, whether by nature or art, is generated or made out of something else; and this something else is called its subject or matter. Such is iron to the saw; such is timber to the boat. Now this subject or matter of a thing being necessarily previous to that thing's existence, is necessarily different from it, and not the same. Thus iron, as iron, is not a saw; and timber, as timber, is not a boat. Hence, then, one character of every subject or matter, that is, the character of negation or privation. [He means negation or privation of what is to be made out of it].

"Again, though the subject or matter of a thing be not that thing, yet, were it incapable of becoming so, it could not be called its subject or matter. Thus iron is the subject or matter of a saw, because, though not a saw, it may still become a saw. On the contrary, timber is not the subject or matter of a saw, because it not only (as timber) is no saw, but can never be made one from its very nature and properties. Hence, then, besides privation, another character of every subject or matter, and that is the character of aptitude or capacity. [He means aptitude or capacity to be that which is made out of it.]

"Again, when one thing is the subject or matter of many things, it implies a privation of them all, and a capacity to them all. Thus iron being the subject or matter of the saw, the axe, and the chisel, implies privation and capacity with respect to all three. Again, we can change a saw into a chisel, but not into a boat; we can change a boat into a box, but not into a saw. The reason is, there can be no change or mutation of one thing into another where the two changing beings do not participate the same

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matter.[1] But even here, were the boat to moulder and turn to earth, and that earth by natural process to metallize and become iron; through such progression as this we might suppose even the boat to become a saw. Hence therefore it is, that all change is by immediate or mediate participation of the same matter. Having advanced thus far, we must be careful to remember, first, that every subject or matter implies, as such, privation and capacity; and, next, that all change or mutation of beings into one another is by means of their participating the same common matter. This we have chosen to illustrate from works of art, as falling more easily under human cognizance and observation. It is, however, no less certain as to the productions of nature, though the superior subtlety in these renders examples more difficult. The question then is, whether, in the world which we inhabit, it be not admitted from experience, as well as from the confession of all philosophers, that substances of every kind,[2] whether natural or artificial, either immediately or mediately pass into one another; and whether, in that case, there must not be some one primary matter common to all things. I say some one primary matter, and that common to all things, since, without some such matter, such mutation would be wholly impossible. But if there be some one primary matter, and that common to all things, this matter must imply, not (as particular and subordinate matters do) a particular privation and a particular capacity, but, on the contrary, universal privation and universal capacity. If the notion of such a being appear strange and incomprehensible, we may farther prove the necessity of its existence from the following considerations: either there is no such general change as here spoken of, which is contrary to fact, and would destroy the sympathy and congeniality of things: or, if there be, there must be a matter of the character here established; because, without it (as we have said), such change would be impossible. Add to this, however hard universal privation may appear, yet had the primary matter, in its proper nature, any one particular attribute, so as to prevent its privation from being unlimited and universal, such attribute would run through all things, and be conspicuous in all. If it were white, all things would be white; if circular, they would be circular; and so as to other attributes; which is contrary to fact. Add to this, that the opposite to such attribute could never have existence, unless it were possible for the same thing to be at once and in the same instance both white and black, circular and rectilineal, &c. since this inseparable attribute would necessarily be everywhere; because the matter, which implies it, is itself everywhere, at least may be found in all things that are generated and perishable.

"Here then we have an idea (such as it is) of that singular being ὑλη πρωτη, *the primary matter;* a being which those philosophers who are immerged in sensible objects know not well how to admit, though they cannot well do without it; a being which flies the perception of every sense, and which is at best, even to the intellect, but a negative object, no otherwise comprehensible than either by analogy or abstraction. We gain a glimpse of it by abstraction, when we say that the first matter is not the lineaments and complexion which make the beautiful face, nor yet the flesh and blood which make those lineaments and that complexion; nor yet the liquid and solid aliments which make that flesh and blood; nor yet the simple bodies of earth and water which make those various aliments; but something which, being below all these, and supporting them all, is yet different from them all, and essential to their existence. We obtain a sight of it by analogy when we say, that as is the brass to the statue, the marble to the pillar, the timber to the ship, or any one secondary matter to any one peculiar form, so is the first and original matter to all forms in general."

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Such is the doctrine of the Peripatetics concerning the primary matter or the basis of bodily substances. We forbear to make any remarks upon it until we have seen what they say of form, the other essential part of every body; for what is meant by matter and form will be most completely seen when they are viewed together.

The Peripatetic doctrine concerning form.

"Form," says the same elegant writer, "is that elementary constituent in every composite substance, by which it is distinguished, characterized, and known from every other. But to be more explicit: the first and most simple of all extensions is a line; this, when it exists, united with a second extension, makes a superficies, and these two existing together, with a third, make a solid. Now this last and complete extension we call the first and simplest form; and when this first and simplest form accedes to the first and simplest matter, the union of the two produces body, which is for that reason defined to be matter triply extended. And thus we behold the rise of pure and original body.[3] It must be remembered, however, that body, under this character, is something indefinite and vague, and scarcely to be made an object of scientific contemplation. It is necessary to this end that its extension should be bounded; for as yet we have treated it without such regard. Now, the bound or limit of simple body is figure, and thus it is that figure, with regard to body, becomes the next form after extension.

"But though the boundary *of* body by figure is one step towards rendering it definite and knowable, yet is not this sufficient for the purposes of nature. It is necessary here, that not only its external should be duly bounded, but that a suitable regard should likewise be had to its internal. This internal adjustment, disposition, or arrangement (denominate it as you please), is called *organization*, and may be considered as the third form which appertains to body. By its accession we behold the rise of *body physical* or *natural;* for every such body is some way or other organized. And thus may we affirm, that these three, that is to say, extension, figure, and organization, are the three original forms to body physical or natural; figure having respect to its external, organization to its internal, and extension being common both to one and to the other. It is more than probable, that from the variation in these universal and (as I may say) primary forms, arise most of those secondary forms usually called quantities sensible, because they are the proper objects of our several sensations. Such are roughness and smoothness, hardness and softness; the tribes of colours, savours, odours; not to mention those powers of character more subtile, the powers electric, magnetic, medicinal, &c.

"Here therefore we may answer the question, how natural bodies are distinguished. Not a single one among them consists of materials in chaos, but of materials wrought up after the most exquisite manner, and that conspicuous in their organization, or in their figure, or in both. As therefore every natural body is distinguished by the differences just described, and as these differences have nothing to do with the original matter, which, being every-

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[1] In a note, he says, "This reasoning has reference to what the ancients called ὑλη προσεχης, *the immediate matter*, in opposition to ὑλη πρωτη, *the remote* or *primary matter*."

[2] He must mean only bodily substances; for it is not admitted by such philosophers as make a distinction between mind and body, that the one ever passes into the other.

[3] "Original body," he says, "when we look downward, has reference to the primary matter, its substratum: when we look upwards, it becomes itself a matter to other things; to the elements, as commonly called, air, earth, water, &c. and in consequence to all the variety of natural productions."

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where similar, can afford no distinction at all; may we not here infer the expediency of essential forms, that every natural substance may be essentially characterized? These forms, though they differ from matter, can yet never subsist without it; but, united with it, they help to produce every composite being, that is to say, in other words, every natural substance in the visible world. It must be remembered, however, that it is the form in this union which is the source of all distinction. It is by this that the ox is distinguished from the horse, not by that grass on which they subsist, the common matter to both. To which also may be added, that as figures and sensible qualities are the only objects of our sensations, and these are all parts of natural form; so therefore (contrary to the sentiment of the vulgar, who dream of nothing but of matter) it is form which is in truth the whole that we either hear, see, or feel; nor is mere matter any thing better than an obscure imperfect being, knowable only to the reasoning faculty by the two methods already explained, I mean that of analogy and that of abstraction. Here, therefore, we conclude with respect to sensible forms, that is to say, forms immerged in matter and ever inseparable from it. In these and matter we place the *elements of natural substance.*"

If this extract appear long, let it be remembered that it contains the fullest and most perspicuous detail which is to be found in the English language, of a doctrine of which the author of Ancient Metaphysics supposes Mr Locke to have been ignorant; and for which ignorance he affects to treat the English philosopher with supercilious contempt. Had Mr Locke really been ignorant of the ancient doctrine of matter and form, it is probable that most people will be of opinion that the contempt expressed by his censurer might have been spared; but if it should appear that, as far as this theory is intelligible, it differs not, excepting in words, from the doctrine laid down in the Essay concerning Human Understanding, what shall we think of that zeal for ancient phrases which had influence sufficient to make one respectable philosopher pour contempt upon another who was an ornament to his country?

Matter cannot be destitute of solidity.

What Mr Harris has said of matter and form respecting works of art, is sufficiently intelligible, and extremely just. Nor should we object to the account which he gives of the origin of natural body, if he had not divested his first matter of every power and every quality, solidity and extension not excepted. But though we can suppose body divested of any one particular figure, and of every sensible quality, such as colour, odour, tastes, &c. and the substratum or basis or matter of it still remain the same, yet it seems impossible to conceive it divested of solidity without supposing it totally annihilated. Nay, if we have any just notion at all of solidity, it is evidently inseparable from the substratum of body, whatever that substratum may be; and indeed, though Mr Harris divests his first matter of every attribute, the argument by which he proves the necessary existence of such a being does not require its privation to be so universal. "Had the primary matter," says he, "in its proper nature, any one particular attribute, so as to prevent its privation from being unlimited and universal, such attribute would run through all things, and be conspicuous in all." This indeed is obvious and undeniable; but solidity and extension do in fact run through all things into which the substratum or matter of body is ever formed, or ever can be conceived to be formed; and therefore there is no necessity for supposing the first matter divested of these attributes.[1]

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Mr Harris mentions that both Timæus and Plato drop expressions as if they considered matter to be place; but place, as will afterwards be seen, can be the basis of nothing. He likewise quotes a passage from Ammonius on the predicaments, in which it is said "that there never was in actuality either matter without body, or body without quality;" and we appeal to our readers if it be not absolutely impossible to contemplate such a thing even in idea. To the question, whether the first matter has a separate existence by itself, distinct from all the qualities of body, the author of Ancient Metaphysics answers thus: "We have no idea of it existing separately, because we find no such a thing in nature, from which we draw all our ideas; but whether there may not be such a thing existing in the regions of infinite space, as matter without form and dimensions, is what I think no man can take upon him to decide." But, with all submission, if a man cannot decide this question with the utmost certainty, his three ponderous volumes are nothing better than useless paper; for the subject of them is things existing; and concerning existence we know nothing with greater certainty than that a being of which nothing positive can be affirmed, cannot possibly have any existence.

Some first matter common to all bodies.

That, in the world which we inhabit, bodily substances of every kind, whether natural or artificial, either immediately or mediately pass into one another, is a truth which

[1] Nor does it appear that it was divested of them by all the ancient philosophers. We learn from Cudworth, that "the atomical physiology, the most ancient perhaps of any, teaches that body is nothing else but διαστατον αντιτυπον, *extended bulk*; and that nothing is to be attributed to it but what is included in the nature and idea of it, viz. greater or less magnitude, with divisibility into parts, figure, and position, together with motion or rest, but so as that no part of body can ever move itself." And, consequently, this philosopher supposes that "there is no need of any thing else besides the simple elements of magnitude, figure, site, and motion (which are clearly intelligible, or different modes of extended substance), to solve the corporeal phenomena by; and therefore not of any substantial forms distinct from the matter; nor of any other qualities really existing in the bodies without, besides the results or aggregates of those simple elements, and the disposition of the insensible parts of bodies in respect of figure, site, and motion; nor of any intentional *species* or *shows* propagated from the objects to our senses; nor, lastly, of any other kind of motion or action really distinct from local motion (such as generation and alteration), they being neither intelligible as modes of extended substance, nor any way necessary: Forasmuch as the forms and qualities of bodies may well be conceived to be nothing but the result of those simple elements of magnitude, figure, site, and motion, variously compounded together, in the same manner as syllables and words in great variety result from the different combinations and conjunctions of a few letters, or the simple elements of speech; and the corporeal parts of sensation, and particularly that of vision, may be solved only by local motion of bodies, that is, either by corporeal effluvia (called *simulacra*, *membranæ*, and *exuviæ*) streaming continually from the surface of the objects, or rather, as the later and more refined atomists conceived, by pressure made from the object to the eye, by means of light in the medium. So that ὡς δια βακτηριας του ταδιντος αιρος το βλεπομενον αναγγιλλεται, the sense taking cognizance of the object by the subtile interposed medium, that is tense and stretched (thrusting every way from it upon the optic nerves), doth by that, as it were by a staff, touch it. Again, generation and corruption may be sufficiently explained by concretion and secretion, or local motion, without substantial forms and qualities. And, lastly, those sensible ideas of light and colours, heat and cold, sweet and bitter, as they are distinct things from the figure, site, and motion of the insensible parts of bodies, seem plainly to be nothing else but our own fancies, passions, and sensation, however they be vulgarly mistaken for qualities in the bodies without us." (Cudworth's *Intellectual System*, book i. chap. i.)

This, as will be seen by and by, is the philosophy of Newton, Locke, and all their followers. And that it is the genuine philosophy of the ancient atomists, we may safely take the word of the author whom we have quoted; for no modern has been more conversant with their writings, more completely master of their language, or has given their sense with greater accuracy. Those authors, therefore, who in their zeal for ancient metaphysics would explode the physiology of Newton and Locke, and substitute in its stead the Aristotelian doctrine of matter and form, belie their own pretences; for the theory which they would banish is more ancient than that which they introduce, and we appeal to our readers if it be not more intelligible.

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cannot be denied; and therefore it follows, that there must be some one primary matter common to all things. In the modern philosophy this primary matter is considered as solid, and as the substratum of all bodies; and all those things which, in the language of Mr Harris, are comprehended under the appellation of form, are called qualities; so that on this subject the ancient and the modern philosophy differ in nothing but in the latter using the word qualities instead of the word form; and defining the first matter to be, "a solid substance everywhere the same," whilst the ancient philosophy considers it as void of solidity.

Of the nature of this, all men are ignorant.

Of the nature of this first matter all philosophers are equally ignorant; for, as Mr Harris says, it is in truth form; or, as modern philosophers would say, they are in truth qualities, which are the whole that we either hear, or see, or feel, or of which we have either idea or conception. Mr Locke says expressly, "that if any one will examine himself concerning his notion of pure substance in general, he will find that he has no other idea of it at all, but only a supposition of he knows not what support of such qualities as are capable of producing simple ideas in us."

How we know that the things perceived are qualities.

But how, it has been asked, do we know that the things which we perceive are qualities, and cannot exist without a subject? We answer, because every one of them, except solidity, may be changed or destroyed, and the subject in which they inhere still remain. Thus, though wax may be melted or burned, and be no longer a hard red substance of such a figure and such a smell, the matter which supported the hardness, figure, colour, and smell, still remains; for melted wax or ashes is as much a solid substance as is that which may be used for the sealing of letters or documents. It has been said that solidity is the substratum of body;[1] and men have been probably led into this notion from a conviction that such substratum, whatever it be, is and must be solid; but that solidity is only a quality inseparable from the first matter, and not that matter itself, must be evident from this consideration, that solidity is the same in all bodies, and incapable of producing by itself any other effect than that of excluding from the place occupied by it every other solid substance. It could not of itself be the substratum of colour, taste, or smell, otherwise all bodies would be coloured, sapid, and odorous; and as, according to all our notions of it, it is incapable of any change, it could not by itself be so modified as to excite in us these sensations.

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Our notion of matter is relative and obscure.

The things, then, immediately perceived by us, or of which we have any adequate idea or conception, are only qualities which must belong to a subject; and all that we know about this subject is, that it is that to which such qualities belong. From this it is evident, that our notion of matter, as distinguished from its qualities, is a relative[2] and obscure notion, and must remain such until men receive other faculties. In this the philosopher seems to have no advantage above the vulgar; for as the latter perceive colour, and figure, and motion, by their senses, as well as he does, and as both are equally certain that there is a subject of those qualities, so the notions which both have of this subject are equally obscure; or, to speak more properly, they have no positive notion of it at all. When a philosopher calls it the first matter, a substratum, or a subject of inhesion, those learned words convey no meaning but what every man understands and expresses, by saying, in common language, that it is a thing extended, solid, and moveable.

They are therefore qualities, or, in the language of ancient philosophy, forms alone, about which, in corporeal substance, we can reason with precision and certainty; and it is sufficient for all the purposes of life that we have of them an adequate knowledge. For as the first matter or original substratum of all bodies seems to be the same, although we know not what it is, and as one body is distinguished from another only by its qualities or powers, a knowledge of the nature of these is all that can be necessary to direct our conduct with respect to the various objects with which we are surrounded.

Qualities primary and secondary.

Qualities thus considered in bodies are, first, such as are utterly inseparable from the body, in what state soever it is; such as, in all the changes and alterations which it suffers, and under all the force which can be employed upon it, it constantly exhibits. Thus, in the instance already given, a stick of sealing-wax may, by the operation of fire, be rendered liquid, or reduced to smoke and ashes; and when it has undergone these changes, it has lost many of the sensible qualities which it had when a long round substance, fit for the purpose of sealing letters; but other qualities which were then perceivable in it still remain; for not only liquid wax, but every particle of smoke and ashes, is solid and extended, as well as the hardest or the largest body; and every such particle has likewise some figure, and is capable of motion or rest. Again, if a grain of wheat, or any other corporeal substance, be divided into

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[1] The philosophers of most eminence who have maintained this opinion are, Dr Watts, the author of Procedure, Extent, and Limits, of the Human Understanding; and Dr Law, the bishop of Carlisle, who, in a note upon King's Origin of Evil, gives the opinion of the triumvirate in the following words. "We find by experience, that a thing will always exhibit the same appearances in some respects, though it admit of changes in others; or, in Mr Locke's language, that certain numbers of simple ideas go constantly together, whereas some others do not. The former of these we call the *substance*, thing, or being, itself; the latter are termed its modes or *accidents*. Thus the substance of *body*, as far as we know of it, consists in solidity and extension; which being necessarily finite, it also becomes capable of division, figure, and motion. These are its original inseparable qualities, which constitute the thing, and seem not to depend on any thing else as a subject. But a particular figure, motion, &c. are only accidents or modes of its existence; which do not necessarily attend it, though they themselves cannot be supposed to exist without it. The substance of spirit consists in the powers of thinking and acting, which likewise admit of various modifications. This seems to be all that we can learn concerning the nature of things from observation and experience. To inquire into the manner how these, which we call properties, exist together, or to attempt to explain the cause, ground, or reason of their union, is in vain. To assign the word substance for a representation of it, is saying nothing; it is setting a mere word for what we have neither any idea of nor occasion for. Indeed if we consider these primary qualities as needing something to inhere in, we are obliged to seek for something to support them; and, by the same way of reasoning, we may seek for something else to support that other something, and so on; and at last shall find no other support for the whole but the cause which produced it." "Dr Watts," continues the Bishop, "is of opinion, that it is introducing a needless scholastic notion into the real nature of things, and then fancying it to have a real existence." (*Logic*, p. 14.) The author of the Procedure, Extent, &c. affirms, "that, as far as we directly know the essential properties of any substance, so far we have a direct knowledge of the substance itself; and if we had a direct knowledge of all the essential properties of any substance, we should have an adequate knowledge of that substance; for surely, if there be any meaning in words, the knowing any thing of the essential properties of a thing is knowing so much of its very substance."

That the substance of body consists in solidity and extension, and nothing more, and that these depend not upon any thing else as a subject, cannot be true; for solidity, in our conception, is nothing but impenetrability; but whoever uses the word impenetrability, certainly means that there is something impenetrable. That there is some real thing or being different from solidity and extension, which impresses us with the notion that it is solid and extended, is self-evident to all mankind. If it be not matter, these conceptions must be communicated to us by the immediate agency of the Deity, which seems to have been the real opinion of the Bishop of Carlisle. But this differs not from the theory of Berkeley, which we shall consider by and by.

[2] Reid's Essays on the Intellectual Powers of Man.

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two parts, and each part be again divided without end, still the smallest particle of it will be solid, extended, of some figure, and capable of further division. Solidity, extension, divisibility, and motion or rest, are therefore qualities inseparable from body, and have on that account been with great propriety called its original or primary qualities.

There are other qualities, which in truth are nothing in the bodies themselves, but powers, arising from the magnitude, the figure, the texture, and the motion, of their insensible parts, to produce in us various sensations. Such are colours, sounds, tastes, and odours. These have been denominated secondary qualities; and to them may be added a third sort, which are universally allowed to be barely powers, though they are in fact as much real qualities in the subject as those we have just mentioned. Thus the power in fire to produce by its primary qualities a new colour or consistency in wax or clay, is as much a quality in the fire as the power which it has to produce in us a new sensation of warmth or burning. That colours, tastes, sounds, and odours, as they are perceived by us, are mere sensations, has been already proved; and that the powers in the bodies which produce these sensations are not, like solidity and extension, inseparable from the body to which they may belong, is evident, because a piece of red wax may be reduced to black ashes, and because, by pounding an almond, we may change its clear white colour into a dirty hue, and its pleasant taste into one that is oily and rancid; and a single rent through the body of a bell destroys its sound.

The primary qualities of body have a real existence independently of us and of every other creature. Thus the particular bulk, number, figure, and motion of the parts of fire or snow are really in the fire or snow, whether any man's senses perceive them or not; and therefore these may be called real qualities, because they really exist in the bodies. But light, heat, whiteness, or cold, as they are perceived by us, are no more really in fire or in snow, than sickness is in tartar or pain in a sword. Take away the sensations of them; let not the eyes see light or colours, nor the ears hear sounds; let not the palate taste nor the nose smell; and all colours, tastes, odours, and sounds, as they are such particular sensations, vanish and cease, and are reduced to their causes, that is, to the bulk, figure, and motion of the parts of the body.

Bodily qualities are of three sorts.

The qualities, then, which are in bodies, rightly considered, are of three sorts. 1. The bulk, figure, number, situation, and motion or rest, of their solid parts. Of these, as they are in themselves, we have clear and distinct notions. We know that they are in the body whether we perceive them or not, and we call them primary or essential qualities. 2. The power that is in any body, by reason of its internal texture and insensible primary qualities, to operate upon our senses in a peculiar manner, producing in us the different sensations of colours, sounds, tastes, or smells, &c. These we have denominated secondary qualities, but they are often termed sensible qualities. 3. The power that is in any body, by reason of the particular constitution of its primary qualities, to effect such a change in the bulk, figure, texture, and motion of another body, as to make it operate on our senses differently from what it did before. Thus, the sun has a power to make wax white, and fire to make lead fluid. These are universally called powers; but we have no such notions of them as we have of the primary qualities of bodies. We know that they exist, but we know not what they are. It has indeed been discovered that the sensation of smell is occasioned by the effluvia of bodies;[1] that of sound by their vibration. The disposition of bodies to reflect a particular kind of light occasions the sensation of colour; and the operation of the minute parts of bodies upon the nerves of the tongue and palate is the cause of tastes. Very curious discoveries have been made as to the nature of heat and its manner of operating, and an ample field still remains. We are likewise intuitively certain, that body can operate upon body only by impulse; but how certain impulses upon certain organs should produce sensations in us to which there is nothing similar in the impelling body, is equally unknown to the clown and the philosopher.

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Doctrine of the ancient atomists.

Such is the distinction which in modern philosophy is made between primary and secondary qualities; but it is a distinction which was likewise well known to that sect of ancient philosophers who were denominated atomists. At the head of these were Thales and Pythagoras; and we may infer from Aristotle, that the sect comprehended almost all the physiologists who had taught before himself and Plato; for he says,[2] "Democritus, and most of the physiologists, fall into a great absurdity, since they make all sense to be touch, and resolve sensible qualities into the figures of insensible atoms." And he adds, that "the former physiologists (without exception) said not well, that there is no black and white without the sight, nor bitter and sweet without the taste." He elsewhere[3] tells us, that those philosophers explained generation and alteration without forms and qualities, by figures and local motion. "Democritus and Leucippus having made figures (or variously figured atoms) the first principles, make generation and alteration out of these, namely, generation together with corruption from the concretion and secretion of them, but alteration from the change of their order and position." By the atomic physiologists the name of quality was very generally applied to those things only which we have called secondary qualities. The primary, being considered as essential to matter, were seldom, if ever, called qualities. That the atoms, which they held to be the first principles of bodies, were figured, solid, extended, and moveable, is apparent not only from the short view of their system which we have given from Cudworth, but likewise from the passages which we have just quoted from Aristotle; but the question debated between them and their antagonists was, whether those atoms had smell, taste, and colour, or, as it was commonly expressed, whether they had qualities. Democritus, Leucippus, and the other atomists, we see, maintained that they had not; and the following account of the doctrine of Protagoras, another philosopher of that school, shows that on this subject at least the ancient advocates for the atomic system reasoned as justly as any of the moderns, and much more justly than the Peripatetics and Platonists, by whom they were opposed. Plato having in his Theœtetus first said in general that the philosophy of Protagoras made all things to consist of a commixture of atoms and local motion, represents his doctrine concerning colours in particular after this manner: "First, as to that which belongs to the sight, you must conceive what is called a white or black colour not to be any thing absolutely existing either without your eyes or within your eyes; but black and white, and every other colour, are caused by different motions made upon the eye, from objects differently modified; so that it is nothing either in the agent or patient absolutely, but something which arises from between them both." From this passage it is plain that Protagoras thought of colours exactly as Mr Locke thought, that they are not real qualities existing in bodies, but merely sensations excited in our minds; and indeed he is presently after represented as having called them *τινα ἐν ημιν φασματα, certain fancies* or

[1] Reid's Essays on the Intellectual Powers of Man, and Locke's Essay on Human Understanding.

[2] *Lib. de Sensu et Sensibili*, cap. iv.

[3] *De Generatione et Corruptione*, lib. i. cap. ii.

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appearances in us. But there is in the Theœtetus another passage, in which a fuller account is given of the atomic philosophy, to this purpose: "The principle upon which all these things depend is this, that the whole universe is motion of atoms, and nothing else, which motion is considered two ways, and is accordingly called by two names, action and passion. From the mutual congress, and, as it were, attrition of these together, are begotten innumerable offsprings, which, though infinite in number, yet may be reduced to two general heads, sensibles and sensations, which are both generated at the same time. The sensations are seeing, hearing, and the like; and the corresponding sensibles are colours, sounds, &c. Wherefore, when the eye and its proper object meet together, both the αἰσθητον and the αἰσθησις, the sensible idea of white and black, and the sensation of seeing, are generated together, neither of which would have been produced if those two had not met. The like is to be conceived of all other sensibles, as hot and cold, &c. None of these are absolutely things in themselves, or real qualities in external objects; but they are begotten from the mutual congress of agent and patient, and that by motion: so that neither the agent has any such thing in it before its congress with the patient, nor the patient before its congress with the agent. But the agent and patient meeting together, and begetting sensation and sensibles, both the object and the sentient are forthwith made to be so and so qualified; as when honey is tasted, the sensation of tasting and the quality of sweetness are begotten together, though the sensation be vulgarly attributed to the taster, and the quality of sweetness to the honey." The conclusion of all which is summed up thus: "Not one of these sensible things is any thing absolutely in the object without, but they are all generated or made relative to the sentient."

The language of the ancient philosophy was defective in precision; terms were used vaguely and improperly, so that the meaning of the author is often to be collected only from the context. When Protagoras is here made to say, that when the agent and patient meet together, both the object and the sentient are forthwith made to be so and so qualified, as, when honey is tasted, the sensation of tasting and the quality of sweetness are begotten together, it could not be his meaning that any real change is made upon the external object merely by our tasting it, but only that the actual sensation and the sensible idea of sweetness are produced at once; just as he had said before that the sensible idea of white or black, and the sensation of seeing, are generated together. If his words be thus interpreted, they express a noble truth; and the whole passage shows that the ancient atomic theory differed little, if at all, from the theory of Descartes, Newton, and Locke, being the most rational, as well as the earliest, system of physics with which we have any acquaintance. By divesting body of essential forms distinct from matter and motion, and by giving to the first matter extension and solidity, it renders the corporeal world intelligible, and accounts for those appearances which are called secondary qualities in a manner perfectly satisfactory. Aristotle indeed opposed the atomic philosophy, and had influence enough to bring it into disrepute for many ages; but when he insisted that the two constituent principles of body are matter and form, both independent of all sentient beings, and which may be conceived as existing distinct from each other, he substituted for a simple and sublime theory an absurd and incomprehensible fiction.

CHAP. II.—OF THE ESSENCES OF BODIES.

Having treated of the substance, qualities, and powers of body, we may seem to have exhausted this part of our subject; but there is still more to be done. Metaphysicians, ancient and modern, have introduced another term into the science to denote that which distinguishes one species or sort of bodies from all other species or sorts; and this term we shall briefly explain. Gold is apparently different from lead, and from every other species of metal; a horse is apparently different from an ox, and from every other species of animals; and all animals apparently differ from all vegetables, as vegetables differ from metals.

Of the Essences of Bodies.

The essences of bodies.

It is only with the bodies, not the minds, of animals, that we are at present concerned; and we have seen that all bodies are composed of the same matter. What then is it that makes different bodies exhibit to us such different appearances, or, in other words, how come they to be possessed of such different qualities and powers? It is, say the followers of Plato and Aristotle, from their having different essential forms, by which every natural substance is essentially characterized; for of every animal, vegetable, or metal, &c. there is a form conceived, as existing before the individuals in which it is incorporated, from which result all the properties of that animal, vegetable, or metal, such as figure, size, colour, and the other qualities perceptible by our senses; but this internal and essential form itself, from which all other forms result, is not perceptible by our senses, nor even by our understanding directly and immediately, nor otherwise than by the analogy formerly mentioned. These essential forms, we are told, mean something, which, although different from matter, can yet never subsist without it; something which, united with it, helps to produce every composite being, that is to say, in other words, every natural substance in the visible world.

Essential forms.

This assertion Mr Harris submits with deference to his contemporaries; because, says he, "I speak perhaps of spectres as shocking to some philosophers as those were to Æneas which he met in his way to hell, *Terribiles visu formæ.*" The elegant author's unwillingness to frighten his contemporaries, was a proof of his amiable and benevolent disposition; but there was no need for his suffering from any such apprehension. Those spectres, apparently so dreadful, had long before been laid to rest by the incomparable Cudworth, who has demonstrated that essential forms different from matter and motion, as they have no real existence, had no place in the most ancient philosophy; and that the different appearances or sensible qualities which different bodies exhibit are the result of the different contexture of their insensible parts. Thus gold and lead are composed of the same primary matter, but the atoms or minute parts of that matter are in the one substance differently combined from what they are in the other; and this different combination is the sole cause that gold is specifically heavier than lead, more ductile, and of a different colour, &c. For the very same reason, iron is harder than either gold or lead, specifically lighter, and possessed of many other sensible qualities which are not found in either of these substances. One vegetable differs from another externally in size, colour, taste, smell, rapidity of growth, and proportion of parts, &c.; but all vegetables are composed of the same matter, and the external difference which prevails among them is the result of a different structure and motion of their insensible parts. The same is to be said of the differences which prevail amongst the bodies of animals; they all result from internal organization and motion, and from nothing else, whatever be the immediate cause of that motion.

These forms have no existence.

This particular internal texture and motion of insensible parts is that which makes one sort of bodies differ externally from every other sort of bodies, and it is by modern metaphysicians called the real essence of bodies. Thus, that internal texture of minute parts, which makes gold of

The real essences of bodies unknown to us.

Of the Existence of Matter.

a bright yellow, extremely ductile, specifically heavier than all other metals, and soluble in *aqua regia*, is the real essence of gold; but what that essence is in itself no man can tell, as we perceive only the qualities which result from it. We are, however, certain that it is different from the real essences of lead and iron, because it produces different effects from those which are produced by these essences, and different effects are never produced in the same circumstances by the same cause.

Nominal essences.

We have called the internal texture and motion of the insensible parts of bodies their real essences, to distinguish them from other essences which are only nominal, and with which we are perfectly acquainted, because they are the fabrication of our own minds. Thus, a beautiful bright yellow, a certain specific gravity, extreme ductility, and solubility in *aqua regia*, are the qualities by which we distinguish gold from all other metals. Of these qualities we frame a sort of general conception, which we call the essence of gold, and every substance in which we find this essence we class under the specific name of gold. For though it is obvious that our conceptions cannot be the real essences of things external, yet are they sufficient guides to these essences, as we know that bodies which, being all formed of the same matter, have the very same sensible qualities, must likewise have the same internal organization or texture of parts, because it is only in that organization or texture that one body can differ from another. So much for bodily substance, qualities, and essences.

CHAP. III.—OF THE EXISTENCE OF MATTER.

Berkeley on the non-existence of matter.

We have endeavoured to prove that all corporeal substances consist of minute atoms, solid and extended; and that the sensible qualities of every body result from the combination and motion of the atoms of which such body is composed. The celebrated Berkeley, bishop of Cloyne, however, attempted to demonstrate that these atoms have no real existence, and that the very supposition of a solid, extended, and inert substance, being the archetype of our ideas, involves in it an absurdity and contradiction.

It is universally allowed that all our knowledge of matter is derived through the senses, either immediately in the very act of sensation, or mediately by an association which is resolvable into a process of reasoning. According to the principles which we have stated and laboured to establish, matter itself is no immediate object of the senses; and as these are the principles upon which the bishop erected his demonstration, it will be incumbent upon us to consider his theory, because it has been represented as in the highest degree pernicious, and as leading to universal scepticism.

The view of his theory given by his antagonists.

The author of the Essay on the Nature and Immutability of Truth represents Berkeley as teaching us, "that external objects (that is, the things which we take for external objects) are nothing but ideas in our minds; in other words, that they are in every respect different from what they appear to be; that matter exists not but in our minds, and that, independent on us and our faculties, the earth, the sun, and the starry heavens have no existence at all; that a lighted candle hath not one of those qualities which it appears to have; that it is not white nor luminous, nor round, nor divisible, nor extended, but that, for any thing we know, or can ever know, to the contrary, it may be an Egyptian Pyramid, the king of Prussia, a mad dog, the island of Madagascar, Saturn's ring, one of the Pleiades, or nothing at all." With respect to the consequences of this theory, he affirms that "it is subversive of man's most important interests as a moral, intelligent, and percipient being; and not only so, but also, that if it were universally and seriously adopted, the dissolution of society, and the destruction of mankind, would necessarily ensue within the compass of a month."

Of the Existence of Matter.

The dissolution of society and the destruction of mankind are indeed dismal consequences, enough to make a man shudder in his closet. But do they really flow from Berkeley's system? They certainly do, if it be the aim of that system to prove that a candle has not any one quality which it appears to have, and that it may be a mad dog; for should all philosophers, by some means or other, become converts to the theory of Berkeley, as we know that the Bishops Sherlock, Smalridge, and others, actually did, the dissolution of society and the destruction of mankind would indeed be inevitable.

A view of his theory given by himself.

But, not to dwell upon such considerations, we beg leave to affirm, that the theory of Berkeley is here totally and grossly misrepresented, and that not one of those dangerous consequences which flow from that misrepresentation can be fairly deduced from any thing taught in the Principles of Human Knowledge, and the Dialogues on the Existence of Matter. So far is Berkeley from teaching that external things are nothing but ideas in our minds, and that they are in every respect different from what they appear to be, that he teaches the very reverse of this in the plainest language possible. "I am of a vulgar cast," observes he, "simple enough to believe my senses, and leave things as I find them. It is my opinion, that the real things are those very things I see and feel and perceive by my senses. That a thing should really be perceived by my senses, and at the same time not really exist, is to me a plain contradiction. When I deny sensible things an existence out of the mind, I do not mean *my* mind in particular, but *all* minds. Now it is plain they have an existence exterior to my mind, since I find them by experience to be independent of it. There is, therefore, some other mind wherein they exist during the intervals between the times of my perceiving them, as likewise they did before my birth, and would do after my annihilation. And as the same is true with regard to all other finite created spirits, it necessarily follows there is an omnipotent eternal mind, which knows and comprehends all things, and exhibits them to our view in such a manner, and according to such rules, as he himself hath ordained, and are by us termed the laws of nature."

So far is Berkeley from teaching that, independently of us and our faculties, the earth, the sun, and the starry heavens have no existence at all, and that a lighted candle has not one of those qualities which it appears to have, that he repeatedly affirms the direct contrary; that the universe has a real existence in the mind of that infinite God, in whom, according to the scriptures, we all live, and move, and have our being; that a lighted candle has not only all those qualities which it appears to have, but that with respect to us it has nothing else; that, so far from being continually deceived by our senses, we are never deceived by them; and that all our mistakes concerning matter are the result of false inferences from true sensations.

The bishop makes the same distinction which we have made between ideas and notions, restraining the use of the former term to denote the relicts of sensation, and employing the latter to denote our knowledge or conception of spirits, and all such objects as are not perceived by sense. He likewise affirms that we can have no idea of an external inert substance, because an idea can be like nothing but another idea, or the sensation of which it is a relict; and as all mankind admit that ideas and sensations can have no existence but in the mind of a percipient being, he therefore infers that we can have no idea of any thing existing unperceived, and by consequence can have no idea of matter in the philosophical sense of that word. Solidity, extension, divisibility, motion, figure, colour, taste, and all those things which are usually called quali-

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ties primary and secondary, being, according to him, mere ideas, can have no existence but in a mind perceiving them; but so far is he from supposing their existence to depend upon the perception of our minds, that he says expressly, "When in broad day-light I open my eyes, it is not in my power to choose whether I shall see or no, or to determine what particular objects shall present themselves to my view; and so likewise as to the hearing and other senses, the ideas imprinted on them are not creatures of my will. There is, therefore, some other will or spirit that produces them. The question between the materialists and me is not, whether things have a real existence out of the mind of this or that person; but whether they have an absolute existence, distinct from being perceived by God, and exterior to all minds. I assert, as well as they, that since we are affected from without, we must allow powers to be without in a being distinct from ourselves. So far we are agreed. But then we differ as to the kind of this powerful being. I will have it to be spirit; they matter, or I know not what third nature. Thus I prove it to be spirit: From the effects I see produced, I conclude there are actions; and because actions, volitions (for I have no notion of any action distinct from volition), and because there are volitions, there must be a will. Again, the things I perceive must have an existence, they or their archetypes, out of my mind; but being ideas, neither they nor their archetypes can exist otherwise than in an understanding; there is, therefore, an understanding. But will and understanding constitute in the strictest sense a mind or spirit. The powerful cause, therefore, of my ideas is, in strict propriety of speech, a spirit."

That theory possible.

This is a faithful abstract of Berkeley's theory, given in his own words. Matter, according to him, cannot be the pattern or archetype of ideas, because an idea can resemble nothing but another idea, or the sensation of which it is a relict. Matter, he thinks, cannot be the cause of ideas; for every cause must be active, and matter is defined to be inert and incapable of action. He therefore infers that all our sensations of what we call the qualities of body are the effects of the immediate agency of the Deity upon our minds; and that corporeal substance has no existence, or at least that we have no evidence of its existence. That such may possibly be the origin of our sensations no man will deny who reflects upon the infinite power and wisdom of the Agent from whom they are conceived to proceed. Dr Reid himself, the ablest of all Dr Berkeley's opponents, frankly acknowledges that no man "can show, by any good argument, that all our sensations might not have been as they are, though no body or quality of body had ever existed."

Harmless in its consequences.

In its consequences we do not perceive that this theory can be hurtful either to religion, to virtue, or to the business of common life; for it only explodes the notion of a substratum, which, though it may have a real existence, was never thought of by the generality of mankind in any nation under heaven. Dr Beattie indeed affirms, that in "less than a month after the non-existence of matter should be universally admitted, he is certain there could not, without a miracle, be one human creature alive on the face of the earth." But this assertion must be the consequence of his mistaking Berkeley's non-existence of matter for the non-existence of sensible objects, the reality and existence of which the bishop never denied. On the contrary, he expressly says, "We are sure that we really see, hear, feel; in a word, that we are affected with sensible impressions; and how are we concerned any farther? I see this cherry, I feel it, I taste it; and I am sure *nothing* cannot be seen, or felt, or tasted; it is therefore real. Take away the sensation of softness, moisture, redness, tartness, and you take away the cherry." All this is equally true, and equally conceivable, whether the combined sensations which indicate to us the existence of the cherry be the effect of the immediate agency of God or of the impulse of matter upon our minds; and to the lives of men there is no greater danger in adopting the former than the latter opinion.

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A consequence of Berkeley's theory.

But it has been said that Berkeley's doctrine necessarily leads to scepticism in religion, as the same kind of reasoning which he employs to prove the non-existence of matter operates equally against the existence of mind, and consequently against the possibility of a future state of rewards and punishments. "The rational issue of this system," we are told, "is scepticism with regard to every thing excepting the existence of our ideas and their necessary relations. For ideas being the only objects of thought, and having no existence but when we are conscious of them, it necessarily follows that there is no object of our thought which can have a continued and permanent existence. Body and spirit, cause and effect, time and space, to which we were wont to ascribe an existence independent of our thought, are all turned out of existence by this short dilemma. Either those things are ideas of sensation or reflection, or they are not: If they are ideas of sensation or reflection, they can have no existence but when we are conscious of them: If they are not ideas of sensation or reflection, they are words without any meaning."

This sophism was advanced as a consequence of Berkeley's principles by Mr Hume; and upon these principles it has been deemed unanswerable by subsequent philosophers of great merit. But is it really a part of Berkeley's system, or can it be fairly inferred from the principles on which that system is built? These questions it is fit that Berkeley should answer for himself; and we shall venture to assert that his answer will be perfectly satisfactory to every reader who attends to the distinction which, after the bishop, we have stated between ideas and notions.

Though we believe that this dangerous inference from Berkeley's principles is commonly attributed to Hume as its author, it did not escape the sagacity of the bishop himself. In the third dialogue, Hylas, who pleads for the existence of matter, thus objects to the reasoning of his antagonist. "Notwithstanding all you have said, to me it seems that, according to your own way of thinking, and in consequence of your own principles, it should follow that you are only a system of floating ideas, without any substance to support them. Words are not to be used without a meaning. And as there is no more meaning in spiritual substance than in material substance, the one is to be exploded as well as the other." To this Philonus answers: "How often must I repeat, that I know or am conscious of my own being; and that I myself am not my ideas, but somewhat else, a thinking active principle, that perceives, knows, wills, and operates about ideas; I know that I, one and the same self, perceive both colours and sounds; that a colour cannot perceive a sound, nor a sound a colour; that I am therefore one independent principle, distinct from colour and sound, and, for the same reason, from all other sensible things and inert ideas. But I am not in like manner conscious either of the existence or essence of matter. Farther, I know what I mean when I affirm that there is a spiritual substance or support of ideas; *i. e.* that a spirit knows and perceives ideas. But I do not know what is meant when it is said that an unperceiving substance hath inherent in it, and supports, either ideas or the archetypes of ideas. In the very notion or definition of material substance there is included a manifest repugnance and inconsistency. But this cannot be said of the notion of spirit. That ideas should exist in what doth not perceive, or be produced by what doth not act, is repugnant. But it is no repugnancy to say that a perceiving thing should be the subject of ideas, or an active being the cause of them. That I, who am a spirit or thinking substance, exist, I know as cer-

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tainly as I know that my ideas exist. I know likewise what I mean by the terms *I* and *myself;* and I know this immediately or intuitively, though I do not perceive it as I perceive a triangle, a colour, or a sound. Ideas are things inactive and perceived; and spirits a sort of beings altogether different from them, by which they are perceived. I do not therefore say that my soul is an idea, or like an idea. However, taking the word idea in a large sense, my soul may be said to furnish me with an idea, that is, an image or likeness of God, though indeed extremely inadequate. For all the notion I have of God is obtained on reflecting on my own soul, heightening its powers, and removing its imperfections. I have, therefore, though not an inactive idea, yet in myself some sort of an active thinking image of the Deity. And though I perceive him not by sense, yet I have a notion of him, or know him, by reflection and reasoning. My own mind and my own ideas I have an immediate knowledge of, and by the help of these do immediately apprehend the possibility of the existence of other spirits and ideas. Farther, from my being, and from the dependency I find in myself and my ideas, I do by an act of reason necessarily infer the existence of a God, and of all created things in the mind of God. It is granted that we have neither an immediate evidence nor a demonstrative knowledge of the existence of other finite spirits; but it will not therefore follow that such spirits are on a footing with material substances; if to suppose the one be inconsistent, and if it be not inconsistent to suppose the other; if the one can be inferred by no argument, and there is a probability of the other; if we see signs and effects indicating distinct finite agents like ourselves, and see no sign nor symptom whatever that leads to a rational belief of matter. I say, lastly, that I have a notion of spirit, though I have not, strictly speaking, an idea of it. I do not perceive it as an idea, or by means of an idea; but know it by reflection. Whereas I neither perceive matter objectively as I do an idea, nor know it as I do myself by a reflex act; neither do I mediately apprehend it by similitude of the one or the other, nor yet collect it by reasoning from that which I know immediately. All which makes the case of matter widely different from that of the Deity and all spirits."

Endeavours to prove the existence of matter impossible.

Thus far we consider Berkeley's theory tenable, and its consequences harmless. That by the immediate agency of the Deity all our sensations might be what they are, although matter had no existence, we think he has proved by arguments unanswerable; and we are likewise of opinion, that by admitting the evidence of sense, consciousness, and reason, in their fullest extent, and by distinguishing properly between those things of which we have ideas and those of which we have notions, he has sufficiently secured the existence of spirits or percipient beings, and obviated the irreligious sophistry of Hume before it was conceived by that author. But the good bishop does not stop here. Not satisfied with proving that all our sensations lead us immediately to the Deity, and that, for aught we know, matter, as defined by philosophers, may have no separate existence, he proceeds farther, and endeavours to prove that matter cannot possibly exist. This appears even in the extracts which we have quoted from his book, in which he talks of the repugnance and inconsistency of the notion. In this part of his system we think he errs greatly, and advances an opinion altogether inconsistent with his own just principles.

His reasoning fallacious.

The repugnance of which he speaks arises solely from considering solidity and extension as relicts of sensation, or as ideas of the same kind with those of heat and cold, tastes and sounds. "Light and colours, heat and cold, extension and figures; in a word, the things we see and feel; what are they," says his lordship, "but so many sensations, notions, ideas, or impressions, on sense: and is it possible to separate, even in thought, any of these from perception? Some there are who make a distinction betwixt primary and secondary qualities; by the former, they mean extension, figure, motion, rest, solidity or impenetrability, and number; by the latter, they denote all other sensible qualities, as colours, sounds, tastes, and so forth. The ideas we have of these they acknowledge not to be the resemblances of any thing existing without the mind, or unperceived; but they will have our ideas of the primary qualities to be patterns or images of things which exist without the mind, in an unthinking substance which they call matter. But it is evident that extension, figure, and motion, are only ideas existing in the mind; that without extension, solidity cannot be conceived; that an idea can be like nothing but another idea; and that consequently neither they nor their archetypes can exist in an unperceiving substance. Hence it is plain, that the very notion of what is called matter or corporeal substance involves a contradiction in it."

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This account of extension and solidity affords a striking instance how much the most vigorous and upright mind is liable to be warped by prejudice in behalf of a darling theory, and how apt the clearest understanding is to be blinded by the equivocal use of terms. That Bishop Berkeley possessed a vigorous and perspicacious mind, his most vehement antagonists are eager to admit; and that his intentions were good, is known to all Europe. Yet by the equivocal use of the word idea, which the writings of Mr Locke had then introduced into the language of philosophy, he has here suffered himself to lose sight of a very proper and accurate distinction, which, as far as we know, was amongst the moderns first made by himself between ideas and notions. According to the bishop, "we have a notion of power and a notion of spirits, but we can have no idea either of the one or the other; for all ideas being passive and inert, they cannot represent unto us by way of image or likeness that which acts. Such is the nature of spirit, or that which acts, that it cannot be of itself perceived, but only by the effects which it produceth. It must be owned, however, that we have some notion of soul, spirit, and the operations of the mind, such as willing, loving, hating, inasmuch as we know or understand the meaning of these words."

Now, we beg leave to state, that what is here said of spirits, and of which we readily admit the truth, is equally true of material or solid substances. We have no ideas of solidity and extension, because these things are not originally impressed upon the senses; but we have very distinct though relative notions of them, for they are clearly perceived by the effects which they produce. That this is at least possible, we have the acknowledgment of Bishop Berkeley himself; for he "freely owns, that from a cause, effect, operation, sign, or other circumstance, there may reasonably be inferred the existence of a thing not immediately perceived; and that it were absurd for any man to argue against the existence of that thing, from his having no direct and positive notion of it." This is exactly the case with respect to solid substances. These substances we do not immediately perceive; but we infer their existence from effects, signs, and other circumstances, and we have very clear though relative notions of them. Thus a man can open and shut his empty hand; but when he grasps an ivory ball of three or four inches diameter, he feels, that though the same power be exerted, his hand cannot then be shut. He is conscious that there is no change in himself; and being intuitively certain that every effect must have a cause, he infers, with the utmost confidence, that the cause which prevents his hand from shutting is in the ball; or, in other words, that the thing which communicates to his eye the sensation of

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colour, and impresses upon his hand a sensation of touch, must be solid or impenetrable. Solidity, however, is not the sensation itself; it is only the cause of the sensation; and therefore it is so far from being an idea in our minds, that we are conscious our notion of it is of a thing totally different from all our ideas of a thing external, at least to our minds. Indeed the notion itself is not positive; it is only relative, and inferred from the effects which are produced upon our senses. That it is the same thing which communicates to the eye the sensation of colour, and has the power of resisting the compression of our hand, is evident, because, when the ball is thrown away, the resistance as well as the actual sensation vanishes at once.

The idea of colour and the notion of solidity not inseparable.

From this fact, which a less acute man would think a proof that the resistance was not occasioned by the immediate agency of the Supreme Being, but by the impenetrability of a solid substance of small dimensions, the bishop argues thus against the possibility of such a substance: "They who assert that figure, motion, and the rest of the primary or original qualities, do exist without the mind in unthinking substances, do at the same time acknowledge that colours, sounds, heat, cold, and such like secondary qualities, do not; which they tell us are sensations existing in the mind alone, that depend on and are occasioned by the different size, texture, and motion, of the minute particles of matter. This they take for an undoubted truth, which they can demonstrate beyond all exception. Now, if it be certain, that those original qualities are inseparably united with the other sensible qualities, and not even in thought capable of being abstracted from them, it plainly follows that they exist only in the mind. But I desire any one to reflect and try whether he can, by any abstraction of thought, conceive the extension and motion of a body, without all other sensible qualities. For my own part, I see evidently that it is not in my power to frame an idea of a body extended and moved, but I must withal give it some colour or other sensible quality, which is acknowledged to exist only in the mind. In short, extension, figure, and motion, abstracted from all qualities, are inconceivable. Where, therefore, the other sensible qualities are, there must be these also, to wit, in the mind, and nowhere else."

In this reasoning, although plausible, there is an unintentional fallacy. It is indeed true that we cannot contemplate in imagination a solid substance without conceiving it to have some colour; but there is sufficient reason to believe that this union of colour and solidity in our minds is not the effect of nature as it operates at first upon our senses, but merely the consequence of early and deep-rooted association. Bishop Berkeley has himself taught us that the objects of sight are not at a distance; and that if a man born blind were suddenly made to see, he would conceive the objects of his sight as existing either in his eye or in his mind. This is a truth which no man will controvert who has dipt into the science of optics, or who has even paid the slightest attention to the perceptions of infants; and if so, it follows, that to a man born blind and suddenly made to see, colour and solidity would not appear united. Were such a person to lay hold of an ivory ball and raise it to the elevation of his eye, he would perceive whiteness as a new sensation existing in his eye or his mind, but he would feel resistance at the extremity of his arm. He would not have the least reason to conclude, that this whiteness was inseparably united to the cause of this resistance; and he would, in fact, draw no such conclusion, till experience had taught him, that by removing the ball or cause of resistance from his hand, he at the same time removed the sensation from his eye. After repeated experiments, he would indeed discover, that the cause of colour to the eye was likewise by some means or other the cause of resistance to the hand; and he would so associate these in his mind, that the one would never afterwards make its appearance as an idea or a notion without bringing the other along with it. The whole difficulty, therefore, in this case, is to break an early and deep-rooted association; for it is plain that the associated ideas were not originally united, and that solidity and colour were at first conceived as separate.

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If the reader perceive not the force of this reasoning, we beg leave to recommend to him the following experiment, which, if we mistake not, will carry conviction to his judgment, that in the last-quoted passage Bishop Berkeley has argued fallaciously, and that extension and colour are not inseparably united as ideas in the mind. Let him go into a dark room, containing a number of spherical bodies of various colours; let him take one of these into his hand, and he will instantly feel resistance, and have a notion of extension and solidity; but will he likewise have the idea of colour inseparably united with this notion? The bishop says he will; and if so, it must be the idea of some particular colour; for his lordship has taught us that the abstract and general idea of colour, which is neither red, nor green, nor blue, &c. cannot possibly be formed. The man, then, we shall suppose, whilst he feels resistance, conceives the resisting body to be green; and holding it still in his hand, walks into the light of day. The resistance, and consequently the cause of resistance, remain unchanged; but what becomes of the inseparable union of those with colour, when the body, upon being actually seen, proves to be black, that is, to have no colour at all? It appears, therefore, undeniable, that solidity and colour are not united in nature; that the one is an essential quality of something external to us, of which we have no idea, but a very distinct though relative notion; and that the other is an actual sensation in our minds, caused by the impression of something external upon the organ of sense, which leaves behind it in the memory or the imagination a positive and direct idea that exists nowhere else.

Matter exists, but is denied to be solid.

Solid substance, therefore, may exist; for although it is not immediately perceived by the senses, and is a thing of which we can have no idea, we acquire a clear and distinct notion of it, by the very same means which Bishop Berkeley thinks sufficient to give us distinct notions of power and of spirits; and, therefore, that notion cannot involve in it a contradiction. Still, however, we would not say with Dr Beattie, "that we could as easily believe that two and two are equal to ten, or that whatever is, is not, as that matter has no separate existence." For it is certainly possible, that the Supreme Being, without the instrumentality of matter, could communicate to our minds all the sensations and notions from which we infer the reality of solid substance. All that we contend for, as having the evidence of demonstration, is the possibility of solid and extended substance; and if the thing be possible, the general voice of mankind proclaims its probability. We are conscious of our actual sensations, and we know by experience that they are caused by something distinct from ourselves. When a man grasps an ivory ball, he feels that he cannot shut his hand, and he knows that the resistance which prevents him proceeds not from himself. Thus far indeed all mankind are agreed. But Bishop Berkeley says, that the resistance proceeds immediately from the Supreme Being, or some other spirit; whilst we, without pretending that his scheme is impossible, think it more natural to suppose that the man's hand is kept from shutting by the resistance of a solid substance of four inches diameter, of which substance, although we have no idea of it, we have as distinct a notion as Berkeley had of spirits. From one or other of these causes this effect must proceed; and it is of little importance to life or happiness which of them be the true

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cause, since it is with the effect only that we are immediately concerned. Still, however, a philosopher would choose to adopt the easiest and most natural side of every alternative, which, if our notion of solidity be just, is certainly, in the present case, the existence of matter.

After treating so largely of the composition of bodies, and showing the general agreement of metaphysicians, ancient and modern, with respect to the notion of their solidity, it will appear strange to the less philosophical part of our readers, that we should now express a doubt of that notion being well founded. We have ourselves no doubt, but on the contrary are fully convinced, that solidity is essential to matter. This, however, has been denied by philosophers of great merit. Dr Priestley, after Mr Mitchell and Father Boscovich, affirms that matter is not solid nor impenetrable to other matter; and that it has, in fact, no properties but those of attraction and repulsion.[1] The proofs of this position, which appears so paradoxical, he draws from optical experiments, from electricity, and from the effects of heat and cold upon substances usually conceived to be solid.

Arguments used in support of this hypothesis.

The appearances from which the solidity of matter is inferred, are nothing more, he says, than superficial appearances, and therefore have led to superficial and false judgments, which the real appearances will not authorize. "Resistance, on which alone our opinion concerning the solidity or impenetrability of matter is founded, is never occasioned by solid matter, but by something of a very different nature, viz. a power of repulsion, always acting at a real, and in general an assignable distance, from what we call the body itself. When I press my hand against the table, I naturally imagine that the obstacle to its going through the table is the solid matter of which it consists; but a variety of philosophical considerations demonstrate that it generally requires a much greater power of pressure than I can exert to bring my fingers into actual contact with the table. Electrical appearances show that a considerable weight is requisite to bring into seeming contact even the links of a chain hanging freely in the air, they being kept asunder by a repulsive power belonging to a very small surface, so that they do not actually touch, though they are supported by each other. It has been shown from optical considerations, that a drop of water rolls upon a cabbage leaf without ever coming into actual contact with it; and indeed all the phenomena of light are most remarkably unfavourable to the hypothesis of the solidity or impenetrability of matter. When light is reflected back from a body on which it seems to strike, it was natural to suppose that this was occasioned by its impinging against the solid parts of the body; but it has been demonstrated by Sir Isaac Newton, that the rays of light are always reflected by a power of repulsion acting at some distance from the body. Again, when part of a beam of light has overcome this power of repulsion, and has entered any transparent substance, it goes on in a right line, provided the medium be of a uniform density, without the least interruption, and without a single particle being reflected, till it comes to the opposite side, having met with no solid particles in its way, not even in the densest transparent substances, as glass, crystal, or diamond; and when it is arrived at the opposite side, it is solely affected by the laws of attraction and repulsion.

"Nay, that the component particles of the hardest bodies themselves do not actually touch one another, is demonstrable from their being brought nearer together by cold, and by their being removed farther from each other by heat. The power sufficient to overcome these internal forces of repulsion, by which the ultimate particles of bodies are prevented from coming into actual contact, is what no person can pretend to compute. The power requisite to break their cohesion, or to remove them from the sphere of each other's attraction, may in some measure be estimated; but this affords no data for ascertaining the force that would be necessary to bring them into actual contact, which may exceed the other almost infinitely."

From these facts Dr Priestley infers, that the mutual resistance of bodies proceeds in all cases from powers of repulsion acting at a distance from each body; that the supposition of the solidity or impenetrability of matter is destitute of all support whatever; and that matter itself is nothing but powers of attraction and repulsion, and several spheres of them, one within another. As other philosophers have said, "Take away solidity, and matter vanishes;" so he says expressly, "Take away attraction and repulsion, and matter vanishes."

To illustrate this strange notion, "Suppose," says he, "that the Divine Being, when he created matter, only fixed certain centres of various attractions and repulsions, extending indefinitely in all directions, the whole effect of them to be upon each other, these centres approaching to or receding from each other, and consequently carrying their peculiar spheres of attraction and repulsion along with them, according to certain definite circumstances. It cannot be denied that these spheres may be diversified infinitely, so as to correspond to all the kind of bodies that we are acquainted with, or that are possible. For all effects in which bodies are concerned, and of which we can be sensible by our eyes, touch, &c. may be resolved into attraction or repulsion. A compages of these centres, placed within the spheres of each other's attraction, will constitute a body that we term compact; and two of these bodies will, on their approach, meet with a repulsion or resistance sufficient to prevent one of them from occupying the place of the other, without a much greater force than we are capable of employing; so that to us they will appear perfectly hard.

"As in the constitution of all actual bodies that we are acquainted with, these centres are placed so near to each other, that in every division that we can make we still leave parts which contain many of these centres; we, reasoning by analogy, suppose that every particle of matter is infinitely divisible; and the space it occupies is certainly so. But, strictly speaking, as those centres which constitute any body are not absolutely infinite, it must be naturally possible to come by division to one single centre, which could not be said to be divisible, or even to occupy any portion of space, though its sphere of action should extend ever so far; and had only one such centre of attraction, &c. existed, its existence could not have been known, because there would have been nothing on which its action could have been exerted; and there being no effect, there could not have been any ground for supposing a cause."

In answer to this reasoning against the solidity of matter, Dr Priestley was frequently asked by his candid and masterly antagonist,[2] "What it is that attracts and repels, and that is attracted and repelled?" But to this question he was never able to give a satisfactory answer. Indeed, how could he have been able? For, as Dr Price argues, "exclusive of attraction and repulsion, he affirms matter to be absolutely nothing; and therefore, though we were to allow it the power of attracting and repelling, yet, as it is nothing but this power, it must be the power of nothing, and the very idea of it be a contradiction."

If there be any class of truths intuitively certain, that class comprehends the two following propositions: *Power*

These arguments fallacious.

[1] Disquisitions on Matter and Spirit, and Correspondence with Dr Price. [2] Free Discussion between Dr Price and Dr Priestley.

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cannot be without a subject; and *Nothing can act where it is not.* If, therefore, there be powers of attraction and repulsion (which shall be considered afterwards in the chapter on Motion), there must be a subject of those powers; and if matter, whether solid or unsolid, be the subject, it cannot possibly attract or repel at a distance. Sir Isaac Newton, in his letters to Dr Bentley, calls the notion that matter possesses an innate power of attraction, or that it can act upon matter at a distance, and attract and repel by its own agency, "an absurdity into which, he thought, no one could possibly fall." Hence it follows, that the appearances from which Dr Priestley infers the penetrability of matter must be fallacious appearances, since they contradict an intuitive and necessary truth. The facts which he instances are, indeed, such as would make most other men suspicious of fallacy; and in his reasonings from them he sometimes takes for granted the truth to be proved. The links of a chain used for electrical purposes, supposing them to be in contact with each other, can touch only with very small surfaces. The electrical fluid is of considerable density, and incapable of being absorbed within a very narrow compass. This is evident, because it passes not through paper and other porous bodies without making a passage for itself, and leaving a visible aperture behind it; and although it assimilates with metals, and passes through them more easily than through other bodies, yet it is plain that it requires a certain quantity of metal to conduct it; for when the conductor falls short of the necessary quantity, it is melted or dissipated by the force of the fluid. This being the case, it follows that the links of a chain may be in actual contact (we do not positively affirm that they are), and yet the fluid become visible in passing from link to link; for if the point of contact be too small to absorb the whole fluid, part of it must pass without any metallic conductor through the atmosphere, and thus become apparent to the eye of the spectator.

With respect to light, it is obvious that there cannot possibly be any demonstration, in the logical sense of the word, that it is reflected by a power of repulsion acting at some distance from the body; for, in the opinion of all mankind, the primary and solid atoms of matter are too minute to fall under the cognizance of our senses, however assisted by art; and therefore, if light appears to be reflected at a distance from the surface of the body, we must conclude, either that between the point of reflection and the apparent surface of the body there are solid atoms unperceived by us, or that light is reflected by the agency of some other substance than matter. One of these conclusions, we say, must be drawn, because they are both possible; and there is no other alternative but to admit one of them, or to suppose that a thing may act where it is not, which is as clearly absurd and impossible as that whatever is, is not. Again, when part of a beam of light has entered any transparent substance, how does Dr Priestley know that it goes on in a right line, without the least interruption, till it comes to the opposite side? This he can know only by his senses; but the beam may meet with ten thousand interruptions from objects which the senses cannot perceive, and may describe a zig-zag line, of which the deflections are so small as to elude the keenest eye aided by the most powerful glass.

That the component particles of the hardest bodies do not all actually touch one another, is indeed evident from the effects of cold and heat upon those bodies; but it does not therefore follow that those bodies have no component particles, but only that they are fewer in number than we are apt to imagine; that all the solid matter in the universe might possibly be compressed within a very narrow sphere; and that it is held together in different bodies and different systems by a power foreign from itself. These are truths which all philosophers have admitted who have thought sufficiently on the subject; but who will admit Dr Priestley's proposition when it is translated into common English, viz. "that the component nothings of the hardest bodies do not actually touch one another, is demonstrable from their being brought nearer together by cold, and by their being removed farther from each other by heat?"

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Dr Priestley owns, that if matter be solid it could act upon other matter by impulse. But we are certain that, whatever it be, it can act upon nothing in the manner which he describes; and therefore, to use the words of Dr Price, "matter, if it be any thing at all, must consist of solid particles or atoms occupying a certain portion of space, and therefore extended, but at the same time simple and uncompounded, and incapable of being resolved into any other smaller particles. It must likewise be the different form of these primary particles, and their different combinations and arrangement, that constitute the different bodies and kinds of matter in the universe." This is exactly agreeable to the doctrine of Newton, who, after considering the question in every point of view, concludes, that "in the beginning God formed matter in solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties, as most conduced to the end for which he formed them; and that those primary particles being solid, are incomparably harder than any porous bodies compounded of them, even so very hard as never to wear or break in pieces, no ordinary power being able to divide what God himself made one in the creation." To talk, as Dr Priestley does, of matter being certain centres of various attractions and repulsions extending indefinitely in all directions, and to describe these centres as not being physical points or solid atoms, is either to say that nothing attracts and repels, or it is to introduce the divine agency as the immediate cause of all our sensations. The former branch of the alternative Dr Priestley disclaims, the latter he seems willing to admit. But if it be his meaning that all our sensations are caused by the immediate agency of God or created spirits, his scheme differs not from that of Berkeley, except in being less elegantly expressed and less ingeniously supported. Berkeley's scheme is evidently possible. The commonly-received scheme is likewise possible. It remains, therefore, with the reader, whether he will adopt the system of the Bishop of Cloyne, or admit, with all other philosophers, that matter exists; that it consists of parts actually distinct and separable; and that each of these parts is a *monad* or solid atom, which requires no foreign agency to keep it united.

Most adequate notion of matter.

CHAP. IV.—OF SPACE AND ITS MODES.

The necessary adjuncts of body.

Having considered bodies in their substance, essences, and qualities, and proved that they have a real existence independently of us and our conceptions, we proceed now to inquire into the nature of space, motion, number, and duration. These are commonly called the adjuncts of body, and are supposed to be absolutely inseparable from its existence. It does not indeed appear that actual motion is a necessary adjunct of body, considered as a mere solid, extended, and figured substance; but it is certainly necessary to the existence of organized and animated bodies, and the capability of being moved enters into our conceptions of all bodies whatever. Of these adjuncts, that which first demands our attention is *space;* for without a knowledge of its nature we could not have an adequate idea of motion, and without motion we could have no idea of time.

Notion of space, how acquired.

Every body is extended; and between two bodies not in actual contact, we perceive that a third body may be easily introduced. That which admits of the introduction of the third body is what we call space, and if it be totally

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void of matter, it is called pure space. Whether there be any space absolutely pure, has been disputed; but that such space is possible admits of no dispute. Were any one body, a cannon ball, for instance, to be annihilated, and the circumambient air, with every other material substance, kept from rushing into the space which the ball had occupied, that portion of space, with respect to matter, would be empty or pure space; whether it would necessarily be filled with mind, shall be considered afterwards. Pure space, therefore, is conceivable; and it is conceived as having three dimensions, length, breadth, and depth, which are generally called the three simple modes of space. In this respect it agrees with body; but the agreement proceeds no farther, for space is conceived as destitute of solidity, without which the existence of body is inconceivable. It has been formerly observed, that whatever may be distinctly conceived may possibly exist; but with respect to the existence of pure space, whatever is possible is real, for it shall be shown in the next section, that were there no space absolutely pure or void of matter, there could be no motion. Our business at present is to inquire what the nature of space is, and what notion we ought to have of its existence.

Many modern philosophers consider space as something entirely distinct both from body and mind; some of them ascribe to it no less than four of the attributes of the Deity, eternity, immobility, infinity, and necessary existence; and a few of them have gone so far as to call infinite space the *sensorium* of the Deity. "The supposal of the existence of any thing whatever," says Dr Clarke,[1] "necessarily includes a presupposition of the existence of space. Nothing can possibly be conceived to exist without thereby presupposing space, which, therefore, I apprehend to be a property or mode of the self-existent substance; and that, by being evidently necessary itself, it proves that the substance of which it is a property must be also necessary." Elsewhere he says, that "space is a property or mode of the self-existent substance, but not of any other substances. All other substances are in space, and are penetrated by it; but the self-existent substance is not in space, nor penetrated by it, but is itself (if I may so speak) the *substratum* of space, the ground of the existence of space itself." He acknowledges, however, that such expressions as "the self-existent substance is the *substratum* of space, or space is a property of the self-existent substance, are not, perhaps, very proper; but what I mean," says he, "is this: The idea of space (as also of time or duration) is an abstract or partial idea; an idea of a certain quality or relation, which we evidently see to be necessarily existing, and yet which (not being itself a substance) at the same time necessarily presupposes a substance, without which it could not exist."

These opinions respecting space have been adopted by succeeding philosophers of great merit, and particularly by Dr Price, who says, that "it is a maxim which cannot be disputed, that time and place are necessary to the existence of all things. Dr Clarke," continues he, "has made use of this maxim to prove that infinite space and duration are the essential properties of the Deity, and I think he was right."

Had authority any weight in philosophy, we know not what modern writers we could oppose to the celebrated names of Clarke and Price, unless it were Bishop Berkeley, Dr Law, bishop of Carlisle, and the author of Ancient Metaphysics. But the question is not to be decided by authority. Learned and acute as Dr Clarke was, his assertions respecting space are contradictory and inconsistent. If nothing can possibly be conceived to exist without thereby presupposing the existence of space, how can space be a property or mode of the self-existent substance? Are properties prior in the order of nature, or even in our conceptions, to the substances in which they inhere? Can we frame an abstract idea of figure, or extension, or solidity, before we conceive the existence of any one figured, extended, or solid substance? These are questions which every man is as capable of answering as Doctors Clarke and Price, provided he can look attentively into his own mind, and trace his ideas to their source in sensation; and if he be not biassed by the weight of great names, we are persuaded he will find, that if it be indeed true, that the supposition of the existence of anything whatever necessarily includes a presupposition of the existence of space, space cannot possibly be a property or mode of the self-existent substance, but must of necessity be a substance itself.

Space necessary to the existence of everything.

It is, however, not true, that the supposal of the existence of any thing whatever necessarily includes a pre-supposition of the existence of space. The idea of space is indeed so closely associated with every visible and tangible object, that we cannot see the one nor feel the other without conceiving them to occupy so much of space. But had we never possessed the senses of sight and touch, we could not have supposed the existence of space necessary to the existence of any thing whatever. The senses of smelling, tasting, and hearing, together with our internal powers of consciousness and intellect, would certainly have compelled us to believe in our own existence, and to suppose the existence of other things; but no object either of consciousness, smelling, tasting, or hearing, can be conceived as occupying space. Space and every thing which fills it are conceived as of three dimensions; but whoever supposed or can suppose an odour, a taste, or a sound, to have length, breadth, and depth; or an object of consciousness to be an ell or an inch in length?

Let us suppose that body and all the visible world had a beginning, and that once nothing existed but that Being who is alone of necessary as well as eternal existence; space, say the followers of Dr Clarke, would then exist likewise without bounds or limits. But we desire to know of these gentlemen what sort of a being this space is. It is certainly not substance; neither is it a property; for we have seen that the very notions of it, which lead men to suppose its existence necessary, render it impossible to be a property of the self-existent Being. Is it then nothing? It "is in one sense;[2] it is nothing actually existing; but it is something potentially; for it has the capacity of receiving body whenever it shall exist. It is not, and cannot become, any thing itself, nor hath it any actual existence; but it is that without which nothing corporeal could exist." And for this reason it was that Democritus and Epicurus made space one of the principles of nature; nay, for the same reason, Aristotle has made privation one of his three principles of natural things, matter and form being the other two. But although the privation of one form be doubtless necessary before matter can receive another (for a piece of wax or clay cannot receive the form of a globe before it lose the form of a square), yet Aristotle never dreamed that the privation of the square was any property of the globe, or that privation itself was to be reckoned a real being. On the contrary, he expressly calls it το μη ὀν, or the *no being*. In this way, if we please, we may consider space, and call it the privation of fulness or of body. We have indeed a positive idea of it, as well as of silence, darkness, and other privations; but to argue from such an idea of space, that space itself is something

[1] Demonstration of the Being and Attributes of God, and Correspondence with a Gentleman in Gloucestershire, *passim*.
[2] Ancient Metaphysics.

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real, seems altogether as good sense as to say, that because we have a different idea of darkness from that of light, of silence from that of sound, of the absence of any thing from that of its presence; therefore darkness, silence, absence, must be real things, and have as positive an existence as light, sound, and body; and to deny that we have any positive idea, or, which is the very same thing, any idea at all, of the privations above mentioned, will be to deny what is capable of the most complete proof, and to contradict common sense and daily experience. There are therefore ideas, and simple ones too, which have nothing *ab extra* correspondent to them; no proper archetype, or objective reality; and we do not see why the idea of space may not be reckoned of that number. To say that space must have existence because it has some properties (for instance, penetrability, or the capacity of receiving body), seems[1] to be the same thing as to urge that darkness must be something because it has the capacity of receiving light; silence the property of admitting sound; and absence the property of being supplied by presence. To reason in this manner is to assign absolute negations; and such as, in the same way, may be applied to nothing, and then call them positive properties; and so infer that the chimera, thus clothed with them, must needs be something.

Space nothing but the possible existence of body.

But it is said, that as we cannot conceive space to be annihilated, it must be some real thing of eternal and necessary existence. If this argument had not been used by writers of great merit, and with the best intention, we should not have scrupled to call it the most contemptible sophism that ever disgraced the page of philosophy. Whatever has now an actual existence, must from eternity have had a possible existence in the ideas of the divine mind. Body, as an extended substance, has now an actual existence, and therefore it must from eternity have had a possible existence in the ideas of the divine mind; but the possible existence of body is all that we can conceive by space, and therefore this argument, upon which so much stress has been laid, amounts to nothing more, than that what has *from* eternity been possible, can at no period have been impossible. It is evident that the capacity or potentiality of every thing existing must have been from eternity; but is capacity or potentiality, a real being? All the men and women who shall succeed the present generation to the end of time have at this moment a possibility of existence, nor can that possibility be conceived as an impossibility; but is it therefore any thing actually existing, either as a substance or a quality?

It has been urged that space must be something more than the mere absence of matter, because if nothing be between bodies, such as the walls of a room, they must necessarily touch. But surely it is not self-evident that bodies must necessarily touch if nothing be between them; nor of the truth of this proposition can anything like a proof be brought. It is indeed intuitively certain, that "things, when they are in contact, have nothing between them;" and hence it has rashly been inferred, that things, when they have nothing between them, are in contact; but this is an illegitimate conversion of the proposition. Every logician knows, that to convert a proposition, is to infer from it another whose subject is the predicate, and whose predicate is the subject, of the proposition to be converted; but we are taught by Aristotle, and by common sense, that an universal affirmative can only be converted into a particular affirmative. "Things, when they are in contact, have nothing between them," is an universal affirmative proposition; and therefore it can only be converted into the following particular affirmative: "Some things, when they have nothing between them, are in contact;" a proposition which by no means includes in it the contact of the walls of an empty room. The reason why the walls of an empty room do not touch, is that they are distant; but is distance, in the abstract, any thing really existing? Two individuals differ, or there is a difference between them; but is difference itself any thing really external? Bodies are long, broad, thick, heavy; but are length, breadth, density, weight, properly any thing? Have they any real separate archetypes or external archetypes? Or can they exist but in some substances?

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The fallacy of supposing space a real thing.

The reason why so many philosophers have considered space as a real external thing, seems to be this. Every bodily substance is extended; but space is conceived to be that which contains body, and therefore to space we likewise attribute extension. Extension is a quality which can have no existence but as united with other qualities in some substance; and it is that of which, abstracted from all substances, we can, properly speaking, form no idea. We understand the meaning of the word, however, and can reason about that which it denotes, without regarding the particular substance in which extension may inhere; just as we can reason about whiteness without regarding any one white object, though it is self-evident that whiteness, abstracted from all objects, cannot figure in the mind as an idea. Qualities considered in this manner are general and relative notions, the objects of pure intellect, which make no appearance in the imagination, and are far less, if possible, to be perceived by sense; but it is extremely painful to the mind to dwell upon such notions, and therefore the ever-active fancy is always ready to furnish them with imaginary substrata, and to make that which was a general and invisible notion be conceived as a particular ideal object. In the case of extension this is the more easily done, that the notion which we have of a real substratum or substance, the support of real qualities, is obscure and relative, being the notion of something we know not what. Now, by leaving, if we can, solidity and figure entirely out of our conception, and joining the notion of something with the notion of extension, we have at once the imaginary substratum of an imaginary quality, or the general notion of extension particularized in an imaginary subject; and this subject we call space, vainly imagining that it has a real external and independent existence. Whether this be not all that can be said of space, and whether it be not absurd to talk of its having any real properties, every man will judge for himself, by reflecting upon his own ideas, and the manner in which they are acquired. We ourselves have no doubt about the matter. We consider pure space as a mere notion relative to the existence of corporeal substance, as in truth nothing more than the absence of body, where body is possible; and we think the usual distinction between absolute and relative space, if taken as real, the grossest absurdity. We do not, however, pretend to dictate to others, but recommend it to every man to throw away all respect for great names, to look attentively into his own thoughts, and on this, as on all metaphysical subjects, to judge for himself.

Place, what it is.

Having said so much of space in general, we need not waste much time upon its modes. Indeed the only mode of space, after considering it with respect to the three dimensions of body, which now demands our attention, is that which we call *place*. For, as in the simplest mode of space we consider the relation of distance between any two bodies or points; so, in our idea of place, we consider the relation of distance between any thing, and any two or more points, which, being considered as at rest, keep the same distance one from another. Thus, when we find any thing at the same distance now at which it was yester-

[1] See Notes on King's Origin of Evil, and Law's Inquiry into the Ideas of Space, &c.

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day from two or more points with which it was then compared, and which have not, since the comparison was made, changed their distance or position with respect to each other, we say that the thing has kept its place, or is in the same place; but if it has sensibly altered its distance from either of these points, we then say that it has changed its place.

From this view of the nature of *place*, we need not observe that it is a mere relation; but it may be worth while to advert to this circumstance, that a thing may without falsehood be said to have continued in the same place, and at the same time to have changed its place according to the different objects with which it is compared. Thus, if two persons find a company of chess-men standing each upon the same square of the chess-board where they left them, the one may with truth affirm that they are all in the same place, or unmoved, and the other may with equal truth affirm that they have all changed place. The former considers the men only with respect to their distances from the several parts of the chess-board, which have kept the same distance and position with respect to one another. The latter must consider the men with respect to their distance from something else; and finding that the chess-board, with every thing upon it, has been removed, we shall suppose, from one room to another, he cannot but say that the chess-men have changed their place with respect to the several parts of the room in which he formerly saw them.

This modification of distance, however, which we call *place*, being made by men for their common use, that by it they may designate the particular position of objects where they have occasion for such designation, they determine this place by reference to such adjacent things as best serve their present purpose, without regarding other things which, for a different purpose, would better determine the place of the same object. Thus, in the chess-board, the use of the designation of the place of each chess-man being determined only within that chequered piece of wood, it would cross that purpose to measure it by any thing else; but when these very chess-men are put up in a box, if any one should ask where the black king is, it would be proper to determine the place by reference to something else than the chess-board, such as the parts of the room or closet which contain the box.

The universe has no place.

That our idea of place is nothing but such a relative position of things as we have mentioned, will be readily admitted, when it is considered that we can have no idea of the place of the universe. Every part of the universe has place, because it may be compared with respect to its distance from other parts supposed to be fixed. Thus the earth and every planet of our system has a place, which may be determined by ascertaining its distance from the sun, and from the orbits of the other planets; and the place of the system itself may be ascertained by comparing it with two or more fixed stars; but all the systems taken as one whole can have no place, because there is nothing else to which the distance and position of that whole can be referred. It is indeed true that the word *place* is sometimes used, we think improperly, to denote that space or portion of space which any particular body occupies; and in this sense, no doubt, the universe has place, as well as the earth or solar system; but to talk of the place of the universe in the other and proper sense of the word, is the grossest absurdity.

CHAP. V.—OF MOTION.

Mobility not natural motion.

Mobility, or a capacity of being moved, is essential to every corporeal substance; and by actual motion are all the operations of nature performed. Motion, therefore, if it may be called an adjunct of body, is certainly the most important of all its adjuncts; and to ascertain its nature and origin demands the closest attention of the metaphysician, as well as of the mechanician and astronomer. With the laws of motion, as discovered by experience, we have at present no concern; they are explained and fully established in other treatises of this work. (See MECHANICS, MOTION, and other articles.) The principal questions which we have to consider are, "What is motion? and by what power is it carried on?"

For an answer to the first of these questions, the modern metaphysician refers every man to his own senses, because, in his apprehension, the word motion denotes a simple idea which cannot be defined. Amongst the ancients, the Peripatetics were of a different opinion; and Aristotle, whose love of dialectics made him define every thing, has attempted to give two definitions of motion. As some learned men have laboured to revive this system, we shall, out of respect to them, mention those definitions, and make such remarks upon them as to us appear proper.

Peripatetic definitions of motion.

The author of Ancient Metaphysics having observed, that both nature and art propose some end in all their operations; that when the end is obtained, the thing operated upon is in a state of perfection or completion; and that in the operations of both nature and art there is a progress, and by consequence a change from one thing to another; adds, that this change is *motion*. Motion, therefore, according to him, is a change or progress to the end proposed, or to that state of perfection or completion which Aristotle calls ἐντελεχεια. It is not enough, however, that we know to what the change or progress is made; to have an adequate idea of motion, we must likewise know from what it proceeds. Now, it is evident that every thing existing, whether by nature or art, had, before it existed, a possible existence; and therefore, adds the same author, things do in some sort exist even before they exist. This former kind of existence is said by Aristotle to be ἐν δυναμει, that is, in power or capacity. In this way, plants exist in their seeds; animals in the embryo; works of art in the idea of the artists and in the materials of which they are made; and, in general, every thing in the causes which produce it. From this power or capacity there is a progress to energy or to actual existence; so that we are now able to answer the question, "from what and to what motion is a change?" for it is universally true of all motion, that it is a change from capacity to energy.

"Having thus discovered that motion lies betwixt capacity and energy, it is evident," he says, "that it must have a connection with each of them; and from this double connection Aristotle has given us two definitions of it; one of them taken from the energy, or end to which it tends; the other from the capacity from which it begins. The first is expressed in two words, viz. ἐνεργεια ἀτελης, or imperfect energy; the other is ἐντελεχεια του ἐν δυναμει, ἡ ἐν δυναμει, "The perfection of what is in capacity, considered merely as in capacity." The meaning of the last words is, that nothing is considered in the thing that is moved but merely its capacity; so that motion is the perfection of that capacity, but not of the thing itself. It is something more, adds the learned author, than mere capacity; for it is capacity exerted, which, when it has attained its end, so that the thing has arrived at that state to which it is destined by nature or art, ceases, and the thing begins to exist ἐνεργεια, or actually.

By all the admirers of Aristotle, this latter definition has been preferred to the former; for what reason, it is difficult to say. They both involve in the thickest obscurity that which, viewed through the senses, is very easily understood; and on this, as on many other occasions, Aristotle was certainly guilty of darkening counsel by words without knowledge. The author, whose comment on this

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wonderful definition we have faithfully abridged, admits that it is not intelligible till we know what change and progress are; but is it possible to conceive any change to take place in bodily substances without motion? or, if we were called upon to explain what progress is, could we do it better than by saying that it is motion from something to something? It is likewise very obvious, that before we can have an adequate idea of motion, we must, according to this definition, know perfectly what the words capacity, energy, and perfection denote; and yet nothing can be more true than that perfection denotes a complex conception, which may be easily defined by resolving it into the simple ideas and notions of which it is compounded, whilst motion is not susceptible of any such resolution. The perfection of a knife is compounded of the temper of the steel and the sharpness of the edge; the perfection of a system of philosophy consists of the importance of the subjects treated, the strength of the author's arguments, and the perspicuity of his style and manner; but of what is the motion of a ball, or an atom, or any thing else, compounded? We are aware that to this question the modern Peripatetics will reply, that it is not the motion of a ball or an atom, nor of any one thing, that their master has so learnedly defined, but motion abstracted from all individuals, and made an object of pure intellect; and they will likewise affirm, that by the word perfection used in the definition, he does not mean any one kind of perfection as adapted to any particular object or end, but perfection abstracted from all objects and all ends. The perfection of nothing and the motion of nothing (for such surely are that motion and that perfection which are abstracted from all objects and ends) are strange expressions. To us they convey no meaning; and we have reason to think that they are equally unintelligible to men of greater acuteness. In a word, motion must be seen or felt; for it cannot be defined. To call it the act of changing place, or a passage from one place to another, gives no information; for change and passage cannot be conceived without previously conceiving motion.

Peripatetic division of motion absurd.

The Peripatetics, having idly attempted to define motion, proceed next to divide it into four kinds or classes. This division was by the father of the school pretended to be made from the effects which it produces, and was said by him to belong to three categories, viz. quality, quantity, and where (see CATEGORY). The first kind is that well-known motion from place to place, which falls under the category last mentioned; the second is alteration, by which the quality of any thing is changed, the substance remaining the same. This belongs to the category of quality. The third is increase, and the fourth diminution, both belonging to the category of quantity. The ancient atomists, and all the modern metaphysicians of eminence, have with great propriety rejected this division, as being nothing but a collection of absurd distinctions where there is in nature no difference. It has already been shown, that body has no other real qualities than solidity, extension, and figure; but of these the first cannot be altered without destroying the substance; for every thing which is material is equally solid. The extension of a body may indeed be enlarged, and its figure may be altered, whilst the substance remains the same; but that alteration can be made only by moving from their places the solid atoms of which the body is composed. Aristotle's second kind of motion, therefore, does not differ from the first; nor do the third and fourth differ from these two. For a body cannot be increased without acquiring new matter, nor diminished without losing some of the matter of which it was originally composed; but matter can neither be added nor taken away without motion from place to place; for there is not now any creation *de novo*; and we have no reason to imagine that, since the original creation, a single atom has ever been annihilated. It is therefore beyond dispute, that local motion is the only motion conceivable; and indeed, as far as we are capable of judging from what we know of body, it is the only motion possible.

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Whether, if but one body existed, there could be motion.

This has given rise to a question which has been debated amongst modern philosophers, though, as far as we know, it was never agitated amongst the ancients, viz. "Whether, if there were but one solid body existing, that body could possibly be moved." Bishop Berkeley seems to be of opinion that it could not; because no motion can be conceived but what has a direction towards some place, and the relation of place necessarily supposes the existence of two or more bodies. Were all bodies, therefore, annihilated excepting one globe, it would be impossible, he thinks, to conceive that globe in motion. With respect to the origin of our ideas of motion, his reasoning appears unanswerable; but we do not perceive how it concludes against the possibility of motion itself as existing in a single body. It has been already shown in the chapter on Simple Apprehension and Conception, that although nothing can be conceived which may not possibly exist, yet many things may be possible which we have not faculties or means to conceive. In the present instance, were this solitary globe animated as our bodies are, were it endowed with all our senses and mental powers, it certainly would not acquire any idea of motion, though impelled by the greatest force. The reason is obvious. It would have no objects with which to compare its place and situation at different periods of time; and the experience of a ship at sea in calm weather affords sufficient proof that motion which is equable cannot be perceived by any other means than by such a comparison. When the waves swell and the ship pitches, it is indeed impossible that those who are on board should not perceive that they are actually in motion; but even this perception arises from comparing their position with that of the waves rising and falling around them; whereas, in the regions of empty space, the animated globe could compare its position with nothing, and therefore, whether impelled by equal or unequal forces, it could never acquire the idea of motion. It may perhaps be thought, that if this solitary globe were a self-moving animal, it might acquire the idea of motion by inferring its existence from the energy which had produced it. But how, we would ask, could any animal in such circumstances be self-moving? Motion is the effect of some cause; and it has been already shown that we have no reason whatever to suppose that any being can be the real and primary cause of any effect which that being can neither conceive nor will; but, as motion can be perceived only by the senses, a solitary animal could have no idea of motion previously to its own exertions, and therefore could neither conceive nor will any exertion to produce it. Let us, however, suppose, that without any end in view it might spontaneously exert itself in such a manner as would produce sensible motion were it surrounded with other corporeal objects; still we may venture to affirm, that, as long as it should remain in absolute solitude, the being itself would acquire no idea of motion. It would indeed be conscious of the mental energy, but it could not infer the existence of motion as a consequence of that energy; for the idea of motion can be acquired only by sense; and by the supposition there are no objects from which the senses of this spherical animal could receive those impressions, without which there can be no perception, and of course no ideas.

Answered in the affirmative.

Let us now suppose that, whilst this animated globe is under the influence either of external impulse or of its own spontaneous energy, other bodies are suddenly brought into existence; would it then acquire the idea of motion? It certainly would, from perceiving its own change of place with respect to those bodies; and although at first it would not perhaps be able to determine whether itself or the bodies around it were moving, yet a little experience

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would decide this question likewise, and convince it that the motion was the effect either of its own mental energy, or of that external impulse which it had felt before the other bodies were presented to its view. But it is obvious that the creation of new bodies at a distance can make no real alteration in the state of a body which had existed before them; and, therefore, as this animated globe would now perceive itself to be moving, we may infer, with the utmost certainty, that it was moving before, and that the motion of a single body, though not perceivable by the senses, might possibly be produced in empty space.

Whether motion would be possible in space absolutely full.

Having thus seen that a single body is capable of motion in empty space, the next question that occurs on this subject is, whether it would be possible to move a body in space that is absolutely full? Such are the terms in which this question is usually put; and by being thus expressed, it has given rise to the dispute amongst natural philosophers about the existence of a vacuum. Perhaps the dispute might have been avoided had the question been more accurately stated. For instance, had it been asked, whether motion would be possible, could matter be supposed absolutely infinite, without any the least interstice or vacuity amongst its solid parts? We apprehend that every reflecting man would have answered in the negative. At any rate, the question ought to be thus stated in metaphysics, because we have seen that space, though a positive term, denotes nothing really existing. Now it being of the very essence of every solid substance to exclude from the place which it occupies every other solid substance, it follows undeniably, that not one particle of an infinite solid could be moved from its place without the previous annihilation of another particle of equal extent, but that annihilation would destroy the infinity. Were matter extended to any degree less than infinity, the motion of its parts would undoubtedly be possible, because a sufficient force could separate those parts, and introduce amongst them vacuities of any extent; but without vacuities capable of containing the body to be moved, it is obvious that no force whatever could produce motion. This being the case, it follows, that however far we suppose the material universe to be extended, there must be vacuities in it sufficient to permit the motion of the planets and all the other heavenly bodies, which we plainly perceive to revolve round a centre; and, if so, the next question to be determined is, what can operate *in vacuo* upon such immense bodies, so as to produce a regular and continued motion?

Bodies equally indifferent to motion and rest.

That all bodies are equally capable of motion or of rest, has been as completely proved by natural philosophers as any thing can be proved by observation and experience. It is indeed a fact obvious to the most superficial observer; for if either of these states were essential to matter, the other would be absolutely impossible. If rest were essential, nothing could be moved; if motion were essential, nothing could be at rest, but every the minutest atom would have a motion of its own, which is contrary to universal experience. With respect to motion and rest, matter is wholly passive. No man ever perceived a body inanimate begin to move, or, when in motion, to stop without resistance. A billiard ball laid at rest on the smoothest surface, would continue at rest to the end of time, unless moved by some force extrinsic to itself. If such a ball were struck by another ball, it would indeed be moved with a velocity proportioned to the impetus with which it was struck; but the impelling ball would lose as much of its own motion as was communicated to that upon which the impulse was made. It is evident, therefore, that in this instance there is no beginning of motion, but only the communication of motion from one body to another; and we may still ask, where had the motion its origin? If the impelling ball was thrown from the hand of a man, or struck with a racket, it is plain, that by a volition of the man's mind the motion was first given to his own arm, whence it proceeded through the racket from one ball to another; so that the ball, the racket, and the arm, were mere instruments, and the mind of the man the only agent or first mover. That motion can be begun by any being which is not possessed of life, consciousness, and will, or what is analogous to these, is to us altogether inconceivable. Mere matter or inanimate body can operate upon body only by impulse; but impulse, although from the poverty of language we are sometimes obliged to talk of its agency, is itself merely an effect; for it is nothing more than the contact of two bodies, of which one at least is in motion. An infinite series of effects without a cause is the grossest absurdity; and therefore motion cannot have been communicated from eternity by the impulse of body upon body, but must have been originally produced by a being who acts in a manner analogous to the energies of the human will.

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Motion produced by impulse can only be in a straight line.

But though motion could not have been begun except by the energy of mind, it is generally believed that it might be continued by the mere passiveness of body; and it is a law of the Newtonian philosophy, that a body projected in empty space would continue to move in a straight line for ever. The only reason which can be assigned for this law is, that since body continues to move at all after the impetus of projection has ceased, it could not of itself cease to move without becoming active; because as much force is required to stop a body in motion as to communicate motion to the same body at rest. Many objections have been made to this argument, and to the law of which it is the foundation; but as we do not perceive their strength, we shall not undertake any formal examination of them. If a single body could exist and have motion communicated to it *in vacuo* by the force of projection, we are persuaded that, from the very passiveness of matter, that motion would never have an end; but it is obvious that it could be moved only in a straight line, for an impulse can be given in no other direction.

The Newtonian doctrine respecting the motion of the heavenly bodies.

The heavenly bodies, however, are not moved in straight lines, but in curves round a centre; and therefore their motion cannot have been originally communicated merely by an impressed force of projection. This is admitted by all philosophers; and therefore the Newtonians suppose that the planets are moved in elliptical orbits by the joint agency of two forces acting in different directions. One of these forces makes the planet tend directly to the centre about which it revolves; the other impels it to fly off in a tangent to the curve described. The former they call gravitation, which some of them have affirmed to be a property inherent in all matter; and the latter, which is a projectile force, they consider as impressed *ab extra*. By the joint agency of such forces, duly proportioned to each other, Sir Isaac Newton has demonstrated, that the planets must necessarily describe such orbits as by observation and experience they are found actually to describe. But the question with the metaphysician is, whether such forces be real?

Mutual attraction of the heavenly bodies.

With respect to projection, indeed, there is no difficulty; but that bodies should mutually act upon each other at a distance, and through an immense vacuum, seems at first sight altogether impossible. If the planets are moved by the forces of gravitation and projection, they must necessarily move *in vacuo;* for the continual resistance of even the rarest medium would in time overcome the force of the greatest impetus; but if they move *in vacuo*, how can they be attracted by the sun or by one another? It is a self-evident truth, that nothing can act but where it is present, either immediately or mediately; because every thing which operates upon another must perform that operation either by its own immediate agency or by means of some instrument. The sun and planets are not in contact; nor,

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if the motion of these bodies be *in vacuo*, can any thing material pass as an instrument from the one to the other. We know indeed by experience, that every particle of unorganized matter within our reach has a tendency to move towards the centre of the earth; and we are intuitively certain, that such a tendency must have some cause; but when we infer that cause to be a power of attraction inherent in all matter, which mutually acts upon bodies at a distance, drawing them towards each other, we employ a language which is perfectly unintelligible.[1] Nay, more; we may venture to affirm that such an inference is contrary to fact. The particles of every elastic fluid fly from each other; the flame of a fire darts upwards with a velocity for which the weight of the circumambient air cannot account; and the motion of the particles of a plant, when growing, is so far from tending towards the centre of the earth, that when a flower-pot is inverted, every vegetable in it, as soon as it is arrived at a sufficient length, bends itself over the side of the pot, and grows with its top in the natural position.

These bodies cannot be moved by two forces *ab extra*.

Sensible of the force of these arguments against the possibility of an attractive power in matter which operates at a distance, other philosophers have supposed that the heavenly bodies are moved in elliptical orbits by means of two forces originally impressed upon each planet, impelling it in different directions at the same time. But if the tendency of the planets towards the centre of the sun be of the same kind with that of heavy bodies towards the centre of the earth (and if there be such a tendency at all, we have no reason to suppose it different), it cannot possibly be the effect of impulse. A body impelled or projected *in vacuo* would continue to be moved with an equable velocity, neither accelerated nor retarded as it approached the object towards which it was directed; but the velocity of a body tending towards the centre of the earth is continually accelerated; and as we cannot doubt but that the same thing takes place in the motion of a body tending towards the centre of the sun, that motion cannot be the effect of impulse or projection.

Nor by the agency of any material fluid.

Some of the Newtonians therefore have supposed "that all kinds of attraction consist in fine imperceptible particles or invisible effluvia, which proceed from every point in the surface of the attracting body, in rectilineal directions every way, which, in their progress, lighting on other bodies, urge and solicit them towards the superior attracting body; and therefore," say they, "the force or intensity of the attracting power in general must always decrease as the squares of the distances increase." The inference is fairly drawn from the fact, provided the fact itself were real or possible. But it is obvious, that if fine imperceptible particles or invisible effluvia were thus issued from every point in the surface of the sun, the earth and other planets could not move *in vacuo*, and therefore the projectile motion would in time be stopped by the resistance of this powerful medium. Besides, is it not altogether inconceivable, nay impossible, that particles issuing from the sun should draw the planets towards that centre? would they not rather of necessity drive them to a greater distance? To say that after they have reached the planets, they change their motion, and return to the place whence they set out, is to endue them with the powers of intelligence and will, and to transform them from passive matter to active mind.

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These difficulties in the theories of attraction and impulse have set philosophers upon fabricating numberless hypotheses. Even Sir Isaac Newton himself, who never considered gravitation as any thing more than an effect, conjectured that there might be a very subtile fluid or ether pervading all bodies, and producing not only the motion of the planets, and the fall of heavy bodies to the earth, but even the mechanical part of muscular motion and of sensation. Others, again, have supposed that fire, or light, or the electric fluid, is the universal agent; and some few have acknowledged, that nothing is sufficient to produce the phenomena but the immediate agency of mind.

With respect to the interposition of any material fluid, whether ether, fire, light, or electricity, it is sufficient to say that it does not remove any one difficulty which encumbers the theory of innate attraction. All these fluids are elastic; and of course the particles of which they are composed are distant from each other. Whatever motion, therefore, we may suppose to be given to one particle or set of particles, the question still recurs, how is it communicated from them to others? If one body can act upon another at the distance of the ten thousandth part of an inch, we can perceive nothing to hinder its action from extending to the distance of ten thousand millions of miles. In the one case as well as in the other, the body is acting where it is not present; and if that be admitted to be possible, all our notions of action are subverted, and it is vain to reason about the cause of any phenomenon in nature.

The hypotheses of Plato, Aristotle, and Cudworth.

This theory of the intermediate agency of a subtile fluid differs not essentially from the vortices of Descartes, which appeared so very absurd to Cudworth, that, with a boldness becoming a man of the first genius and learning, he rejected it, and adopted the plastic nature of Plato, Aristotle, and other Greek philosophers. That incomparable scholar observes, that matter, being purely passive, the motion of the heavenly bodies, the growth of vegetables, and even the formation of animal bodies, must be the effect either of the immediate agency of God, or the agency of a plastic

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[1] A different opinion on this point is held by Mr Dugald Stewart in his *Elements of the Philosophy of the Human Mind*. We shall, however, claim the same liberty of dissenting occasionally from him that he has claimed of dissenting from Newton, Locke, Clarke, and Cudworth, from whom he differs widely in thinking it as easy to conceive how bodies can act upon each other at a distance, as how one body can communicate motion to another by impulse. "I allow," says he (p. 79), "that it is impossible to conceive in what manner one body acts upon another at a distance through a vacuum; but I cannot admit that it removes the difficulty, to suppose that the two bodies are in actual contact. That one body may be the efficient cause of the motion of another body placed at a distance from it, I do by no means assert; but only that we have as good reason to believe that this may be possible, as to believe that any one natural event is the efficient cause of another."

If by efficient cause be here meant the first and original cause of motion, we have the honour to agree with the learned professor; for we are persuaded, that body inanimate is not, in this sense of the word, the cause of motion either at hand or at a distance. But if he mean (and we think he must, because such was the meaning of Newton, from whom he professes to differ), that we can as easily conceive one body to be the instrumental cause of the motion of another from which it is distant, as we can conceive it to communicate motion by impulse, we cannot help thinking him greatly mistaken. We will not indeed affirm, with the writer whom he quotes, "that although the experiment had never been made, the communication of motion by impulse might have been predicted by reasoning *a priori*;" because we are not certain, that without some such experiment we should ever have acquired adequate notions of the solidity of matter. But if all corporeal substances be allowed to be solid, and possessed of that negative power to which philosophers have given the name of *vis inertiæ*, we think it may be easily proved *a priori*, that a sufficient impulse of one hard body upon another must communicate motion to that other; for when the *vis inertiæ*, by which alone the one body is kept in its place, is less than the *vis impetus* with which the other rushes to take possession of that place, it is evident that the former body must give way to the latter, which it can do only by motion, otherwise the two bodies would occupy one and the same place, which is inconsistent with their solidity. But that a substance possessed of a *vis inertiæ* should make another substance possessed of the same negative power quit a place to which itself has no tendency, is to us not only inconceivable, but apparently impossible, as implying a direct contradiction.

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nature employed as an instrument by Divine Wisdom. That they are not the effect of God's immediate agency, he thinks obvious from several circumstances. In the first place, they are performed slowly and by degrees, which is not suitable to our notions of the agency of Almighty Power. Secondly, many blunders are committed in the operations of nature, such as the formation of monsters, &c. which could never be were things formed by the immediate hand of God. He is therefore of opinion, that after the creation of matter, God employed an inferior agent to give it motion and form, and to carry on all those operations which have been continued in it since the beginning of the world. This agent he calls plastic nature; and considers it as a being incorporeal, which penetrates the most solid substance, and, in a manner which he pretends not to explain otherwise than by analogy, actuates the universe. He does not look upon it as a being endued with perception, consciousness, or intelligence, but merely as an instrument which acts under Divine Wisdom, according to certain laws. He compares it to art embodied; and, quoting from Aristotle, says, "If the art of the shipwright were in the timber itself, operatively and effectually, it would there act just as nature does." He calls it a certain lower life than the animal, which acts regularly and artificially for ends of which it knows nothing. It may be, he says, either a lower faculty of some conscious soul, or else an inferior kind of life or soul by itself, but depending in either case upon a higher intellect. He is aware with what difficulty such a principle will be admitted by those philosophers who have divided all being into such as is extended and such as is cogitative; but he thinks this division improper. He would divide beings into those which are solid and extended, and those which have life or internal energy. Those beings which have life or internal energy he would again divide into such as act with consciousness, and such as act without it; the latter of which is this plastic life of nature. To prove that such an instrument is possible, or that a being may be capable of operating for ends of which it knows nothing, he instances bees and other animals, who are impelled by instinct to do many things necessary to their own preservation, without having the least notion of the purpose for which they work. (See INSTINCT.) He observes, that there is an essential difference between reason and instinct, although they are both the attributes of mind or incorporeal substance; and that therefore, as we know of two kinds of mind differing so widely, there is nothing to hinder us from inferring a third, with powers differing as much from instinct as instinct differs from reason. Mankind are conscious of their own operations, know for what purpose they generally act, and can, by the power of reflection, take a retrospective view of their actions and thoughts, making as it were the mind its own object. Brutes are conscious of their own operations, but they are ignorant of the purposes for which they operate, and altogether incapable of reflecting either upon their past conduct or their past thoughts. Between their intellectual powers and those of man there is a much greater difference than there is between them and a plastic nature, which acts as an instrument of Divine Wisdom, without any consciousness of its own operations. Aristotle, from whom principally the learned author takes this notion of this plastic nature, compares it, with respect to the Divine Wisdom which directs and superintends its operations, to a mere builder or mechanic working under an architect, for a purpose of which the mechanic himself knows nothing. The words of the Stagyrite are, "We account the architects in every thing more honourable than the mere workmen, because they understand the reason of the things done; whereas the other, as some inanimate things, only work, not knowing what they do, just as the fire burns; the difference between them being only this, that inanimate things act by a certain nature in them, but the workman by habit."[1]

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Still further to prove that a being may be endowed with some vital energy of a subordinate kind, and yet be destitute of consciousness and perception, the learned author observes, that there is no reason to think that the souls of men in sound sleep, lethargies, or apoplexies, are conscious of any thing; and still less, if possible, to suppose that the souls of embryons in the womb are, from the very first moment of their arrival there, intelligent and conscious beings; neither can we say how we come to be so differently affected in our souls by the different motions made upon our bodies, nor are we always conscious of those energies by which we impress fantastic ideas on the imagination. But if it be possible for the souls of men to be for one instant void of consciousness and intelligence, it follows that consciousness is not absolutely necessary to those energies and motions by which life is preserved. To this it may be added, upon the best authority,[2] "that where animal or vegetable life is concerned, there is in every case a different relation between the cause and effect, and seemingly depending upon the concurrence or influence of some farther principle of change in the subject than what subsists in inanimate matter, or in the causes and effects that are the objects of mechanical and chemical philosophy." Now to this principle of vegetable life, without which, in a seed or in a plant, vegetation will neither begin nor continue, though light, heat, air, earth, and water, should concur in the utmost perfection, Cudworth expressly compares his plastic nature in the universe. It is so far, says he, from being the first or highest life, that it is indeed the last and lowest of all lives, being really the same thing with the vegetative.

Possibility of these hypotheses.

These arguments, if the phenomena of elective attractions in chemistry be added to them, demonstrate, we think, the possibility of such a principle; and to those who are inclined to affirm that no such thing can exist, because, according to the description of it given by Cudworth and the ancients, it is neither body nor spirit in the proper sense of the words, we beg leave to ask, in the words of Locke, "who told them that there is and can be nothing but solid beings which cannot think, and thinking beings that are not extended, which is all that they mean by the terms body and spirit?" All the Greek philosophers who were not materialists, and even the inspired writers of the Old and New Testaments, constantly distinguish between the *spirit* and the *soul* of a man, calling the former sometimes νους, and sometimes πνευμα, and the latter ψυχη; and St Paul, who, before he was a Christian, was learned in philosophy, describes the constituent parts of man as three, πνευμα, ψυχη, σωμα, spirit, soul, and body. This distinction, setting aside the authority with which it comes to us, seems to be well founded; for there are many operations carried on in the human body without any conscious exertion of ours, and which yet cannot be accounted for by the laws of mechanism. Of these, Cudworth instances the motion of the diaphragm and other muscles which cause respiration, and the systole and diastole of the heart, neither of which, he thinks, can be the effect of mere mechanism. But, as we are not conscious of any energy of soul from which they proceed, even whilst we are awake, and still less, if possible, whilst we are asleep, he attributes them, not to the intellect or rational mind, but to this inferior vital principle called ψυχη, which, in his opinion, acts the same part in the system of the human body which the plastic nature acts in the system of

Arguments for its truth.

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[1] Metaphys. lib. i. cap. i.

[2] Gregory's Philosophical and Literary Essays.

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the world. To make the resemblance still more striking, he observes, that even the voluntary motion of our limbs, although it proceeds ultimately from an energy of will, seems to be the effect of that energy employing some instrument which pervades the sinews, nerves, and muscles of the body; and if the human spirit or πνευμα employ the instrumentality of a plastic nature or ψυχη in moving the small machine of the body, it seems to be far from incredible that the Divine Wisdom should employ the instrumentality of a plastic nature in moving the great machine of the universe.

Celestial motions carried on by the agency of something incorporeal.

But we need not insist further on the possibility of such an instrument. Whatever may be thought of the arguments of Cudworth, of which some are, to say the least of them, plausible, though others appear to us to have very little strength, Dr Clarke has proved, with a force of reasoning not inferior to mathematical demonstration, that the motions of the heavenly bodies are carried on by the agency of something very different from matter, under every possible form. "For, not to say that, seeing matter is utterly incapable of obeying any laws in the proper sense of the word, the very original laws of motion themselves cannot continue to take place but by something superior to matter continually exerting on it a certain force or power, according to such certain and determined laws, it is now evident beyond question, that the bodies of all plants and animals could not possibly have been formed by mere matter according to any general laws of motion; and not only so, but that most universal principle of gravitation itself, the spring of almost all the great and regular inanimate motions in the world, answering not at all the surfaces of bodies, by which alone they can act upon one another, but entirely to their solid contents, cannot possibly be the result of any motion originally impressed upon matter." For although it is true that the most solid bodies with which we are acquainted are all very porous, and that therefore a subtile material fluid might penetrate the bodies of the planets, and operate upon them with a force exerted internally, still it is self-evident that the greatest quantities of such a fluid could not enter into those bodies which are least porous, and where the greatest force of gravitation resides; "and, therefore, this motion must of necessity be caused by something which penetrates the very solid substance of all bodies, and continually puts forth in them a force or power entirely different from that by which matter acts upon matter."[1] This, as the same able writer observes, is an evident demonstration, not only of the world's being originally made by a Supreme Intelligent Cause; but, moreover, that it depends every moment upon some superior being for the preservation of its frame, and that all the great motions in it are caused by some immaterial power perpetually and actually exerting itself every moment in every part of the corporeal universe. This preserving and governing power, whether it be the immediate power and action of the same Supreme Cause that created the world, or the action of some subordinate instruments appointed by him to direct and preside respectively over certain parts thereof, gives us equally in either way an elevated idea of Providence. We know with certainty that real and original power can belong only to a being endowed with intelligence and will; and, therefore, if the existence of Cudworth's plastic nature be admitted, and we see not why it should be called in question, it can be considered only as an instrument employed by Divine Wisdom, as a chisel or a saw is employed by the wisdom of the mechanic.

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Nor let it be imagined, that this ancient theory of motion is in any degree inconsistent with the mathematical principles of Sir Isaac Newton's astronomy, or with the calculations derived from those principles. Having founded his astronomy on analogy between the phenomena of projectile and planetary motions, he assigned the same or similar forces existing in nature as the efficient causes of both. And indeed, both in the act of deriving his principles from the projectile phenomena, and afterwards for the purpose of applying them to the planetary, it was necessary to analyze the elliptical motion of the heavenly bodies into a compound of two simple motions in right lines, produced by the action of these different forces; and this might also be useful for the purposes of teaching and demonstration, just as we find it necessary, in almost all parts of science, to separate what in nature is inseparable, for the convenience and assistance of the understanding. The planetary motions, however, are very probably simple and uncompounded, for no experiments can be tried in those distant regions; and the astronomy of Newton, which is only the application of his mathematical principles to their mensuration from their analogy to projectile motions, does not at all require that the forces of gravitation and projection be assigned as their real existent causes.[2] It is sufficient for the analogy, on which the whole philosophy is founded, that the phenomena of motion are known from experiments and observations to be the same in both instances; that the principles or general laws mathematically established from the forces of the one are transferred to the phenomena of the other; and that the proofs and operations deduced from these principles in the latter case, are confirmed by facts and experience, the first and final test of truth.[3]

This theory not inconsistent with the principles of Newton.

CHAP. VI.—OF NUMBER.

Unity, as an idea, cannot be abstracted from every individual.

"Amongst all the ideas that we have, as there is none," says Mr Locke,[4] "suggested to the mind by more ways, so there is none more simple, than that of *unity*, or one. It has no shadow of variety or composition in it. Every object our senses are employed about, every idea in our understandings, every thought of our minds, bring this idea along with it; and therefore it is the most intimate to our thoughts, as well as it is, in its agreement to all other things, the most universal idea we have; for number applies itself to men, angels, actions, thoughts, every thing that either doth exist or can be imagined." He seems likewise to be of opinion, that we have the idea of unity before that of many; and that it is by repeating the simple idea of unity in our own minds that we come by the complex ideas of two, three, or more. In this opinion he is joined by Père Buffier,[5] who observes, that it is impossible to explain the nature of unity, because it is the most simple idea, and that which perhaps first occurred to the mind.

That unity is a simple idea, must be granted; but it cer-

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[1] Evidence of Natural and Revealed Religion.

[2] Indeed Sir Isaac himself is very far from positively assigning them as the *real* causes of the phenomena. The purpose for which they were introduced into his philosophy he clearly explains in the following words: "Eadem ratione qua projectile vi gravitatis in orbem flecti posset et terram totam circumire, potest et luna, vel vi gravitatis, *si modo gravis sit*, vel alia quacunque vi qua in terram urgeatur, retrahi semper a cursu rectilineo terram versus et in orbem suum flecti; et absque tali vi luna in orbe suo retineri non potest. Hæc vis, si *justo minor* esset, non satis flecteret lunam a cursu rectilineo: si *justo major*, plus satis flecteret, ac de orbe terram versus deduceret. Requiritur quippe ut sit *justæ magnitudinis*: et mathematicorum est invenire vim, qua corpus in dato quovis orbe data cum velocitate accurate retineri possit; et vicissim invenire viam curvilineam, in quam corpus e dato quovis loco data cum velocitate egressum data vi flectatur." (*Principia Mathem.* def. v.)

[3] Tatham's Chart and Scale of Truth.

[4] Essay, book ii. chap. xvi.

[5] First Truths.

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tainly did not first occur to the mind, nor can it be abstracted from all individuals, and apprehended, in Locke's sense of the word, as a general idea. Let any man look into his own mind, and then say whether he has a general idea of one or of unity as abstracted from every individual object mental and corporeal. In particular, when he thinks he has completely abstracted it from body and mind, sensations, ideas, actions, and passions, &c. let him be sure, before he pronounce it a general abstract idea, that he is not all the while contemplating the idea of its name, or of that numerical figure by which it is marked in the operations of arithmetic. Both these ideas are in themselves particular; and become general in their import, only as representing every individual object to which unity is in any sense applicable. But, in the chapter on Abstraction, we have said enough to convince every person capable of conviction, that they are employed as signs for whole classes of objects.

Instead of being an abstract general idea, unity, as the basis of number, is in fact nothing but a mere relation, which cannot be conceived without the related objects; and so far is it from being the first idea that occurred to the mind, that it is certainly the result of a comparison, made by the intellect, of two or more objects. The ideas which first occur to the mind are, beyond all doubt, those which are called ideas of sensation; and many such ideas every child receives before he is capable of comparing objects and forming to himself notions of number. Unity, or the idea of one, is indeed the element of the science of arithmetic, just as a mathematical point is the element of the science of geometry; but accurate notions of these elements are, in the progress of knowledge, subsequent to ideas of many and of surfaces. There is reason to believe that persons totally illiterate have no notion at all of mathematical points; and we think it possible to conceive an intelligent and conscious being in such a situation as that he could not acquire a notion of unity or one. Were a child never to see or feel two objects of the same kind, we doubt if he would think of numbering them, or of making such a comparison of the one with the other as would suggest to his mind the relations of one and two; for these relations imply both a sameness and a difference of the objects beyond the power of a child to ascertain. The difference indeed would be perceptible to the senses, but the senses would perceive no sameness or agreement. A guinea, a shilling, and a ball of lead, impress upon the mind different sensations; and therefore a child undoubtedly distinguishes these objects from one another; but what could make him derive from this his first idea of the relation of number? A guinea, a shilling, and a ball of lead, are not one, two, three, in any sense which a child can comprehend. To be convinced of this, let any man throw a guinea, a shilling, and a ball of lead upon a table, and ask a clown what is their number. From being accustomed to retail the names of number as signs, without affixing to them any idea of the things signified, he will probably answer with quickness three, or perhaps one, two, three. But if he be further asked in what respect they are one, two, three, we believe his answer will not be so ready. They are not one, two, three guineas, or shillings, or balls of lead. A philosopher knows them to be three pieces of the same first matter under different forms, and can therefore apply to them the relation of number with truth and propriety; but of the first matter a clown is entirely ignorant, and of course cannot call them one, two, three, in any sense which is at once true and to him intelligible.

Unity a particular relation.

To make it still more evident that it is only by comparing together things of the same kind that our first ideas of unity and number are formed, let us suppose that no created being had hitherto existed except the animated and intelligent globe mentioned in the last chapter, and we think it will be granted that such a being in solitude could never acquire the idea of unity. Let us next suppose a cubical body to be created, and exhibited to the senses of this spherical man. The consequence would be a sensation or feeling entirely new, but that feeling would not be one of unity; for, as the author of Ancient Metaphysics has somewhere well observed, unity is no object of sensation. The sensation would be one of colour, hardness, softness, roughness or smoothness, &c. for beyond these the empire of the senses does not reach. Again, let another body be created of a colour and figure totally different from the colour and figure of the cube, and the spherical man would then experience new sensations having no agreement with those which he had formerly felt. These different kinds of sensations might be compared together; but the result of the comparison would not be the ideas which are denoted by the words one and two, but merely that which is expressed by difference or dissimilarity. Were another cube, however, of exactly the same size and colour with the former to be brought into existence, and both to be at once presented to the view of the spherical man, the rudiments of the idea of number would then be generated in his mind, because he could not but perceive the cubes to be in one respect different and in another the same; different as being distinct from each other, and agreeing in their effects upon the organs of sensation.

Notion of number.

It appears, therefore, that mankind must have made some progress in classing things according to their genera and species, before they acquired any correct ideas of the relation of number, or thought of using numerical names or figures as general and discriminating signs; for we say one, two, three, &c. only with respect to the species or genus of which each of the things denoted by these numbers is an individual; and if there be any thing which has no genus or species, neither number nor unity can, in the original sense of the words, be predicated of it.[1] We say indeed that there is one God; but perhaps we do not always attend to the meaning of the expression. Language was formed to answer the common purposes of life; and those purposes are best answered by denoting individuals by the name of the species or genus to which they belong. But God belongs to no species or genus, unless he be said improperly to be of the universal genus of Being; and therefore the true meaning of the word "one," when joined to the verb "is," and transferred from the creature to the Creator, in such a sentence as "There is one God," seems to be nothing more than an affirmation that God exists, and that to him the relation of number cannot be applied. In a word, unity and number are merely relations between

[1] We are happy to find our notions on this subject confirmed by Mr Dugald Stewart. "Without the power of attending separately to things which our senses present to us in a state of union, we never," says this able writer, "could have had any idea of *number*: for, before we can consider different objects as forming a multitude, it is necessary that we should be able to apply to all of them one common name; or, in other words, that we should reduce them all to the same genus. The various objects, for example, animate and inanimate, which are at this moment before me, I may class and number in a variety of different ways, according to the view of them that I choose to take. I may reckon successively the number of sheep, of cows, of horses, of elms, of oaks, of beeches; or I may first reckon the number of animals, and then the number of trees; or I may at once reckon the number of all the organized substances which my senses present to me. But whatever be the principles on which my classification proceeds, it is evident that the objects numbered together must be considered in those respects only in which they agree with each other; and that if I had no power of separating the combinations of sense, I could never have conceived them as forming a plurality." (*Elements of the Philosophy of the Human Mind*, chap. iv.)

Of Time. the individuals of the same species or genus of being; and men acquire ideas of these relations at the same time and by the same means that they are led to class things into species and genera. As to the processes of addition and subtraction, and the various purposes to which number is applied, these things belong to the science of arithmetic, and do not fall under the province of the metaphysician, whose sole object is to ascertain the real nature and causes of things. It may, however, be worth while to observe, that Locke, whose notions of number seem to have been different from ours, owns, that a man can hardly have any ideas of numbers of which his language does not furnish him with names. But if units were either real things, or even positive ideas, we see not how names could be necessary to their existence; whereas, if they be nothing more than mere relations, it is obvious that they cannot be conceived but as relative either to beings actually existing, or to names which are the signs of actual beings.

CHAP. VII.—OF TIME.

Time a mode of duration.

When St Augustin was asked what time is, he replied, "*Si non roges, intelligo;*" an answer from which it may be inferred that he thought the nature of time could not be explained by a logical definition. Time and eternity are commonly considered as the two modes of duration; and if duration be taken in what Locke thinks its true and original sense, to denote permanence of existence, with a kind of resistance to any destructive force, the distinction seems to be sufficiently proper. It is indeed the best that we can make or comprehend; for duration, time, and eternity, are subjects which have perplexed philosophical minds in all ages, and of which, if we have any adequate notions, it is very difficult to express these notions in language. Instead of attempting it by previous definitions, the method in which the ancients generally began their inquiries, we shall pursue the better course of induction recommended by Lord Bacon, and endeavour to show by what means we acquire the notion of that mode of duration which is called time, in contradistinction to eternity. We begin with time, because we ourselves exist in it, and it is in some sense familiar to us. If we be able to trace our notions of this mode of duration to their source, we may then give a definition of it founded upon fact and universal experience, and afterwards proceed to consider the other mode in conjunction with infinity, to which it is nearly allied.

Whilst the mind is occupied by one idea there is no perception of time.

It has already been observed, that every man, whilst awake, has a train of sensations and ideas constantly passing through his mind, in such a manner that the one succeeds the other in a regular order. It is not possible, either by detaining in the mind one idea to the exclusion of all others, to stop the course of this succession entirely; or, by hurrying some ideas off the stage, and calling others in their place, to quicken its progress beyond a certain degree. One man indeed has naturally a quicker succession of ideas than another; and all men can, by great exertions, accelerate or retard in a small degree the natural current of their thoughts. A studious man lays hold, as it were, of a particular idea, which he wishes to contemplate, and detains it in the imagination, to the exclusion of all others; a man of wit calls remote ideas into view with a rapidity of which a cool and phlegmatic reasoner cannot form any conception; and a forcible sensation takes full possession of the mind, to the exclusion of all ideas whatever. Whilst the attention is wholly occupied by one idea, or by one sensation, the mind has no notion whatever of time; and were it possible to detain such idea or sensation alone in the mind till the hand of a clock should move from the number of one hour to that of another, the hour, as marked on the dial-plate and measured by the motion of the hand, would appear but as one instant absolutely void of duration. For the truth of this assertion we appeal to the experience of our readers. Such of them as have ever been engaged in deep study must often have had their attention so fixed upon one object, that large portions of time, as measured by the clock, have passed away wholly unheeded; and every man who has seen a very striking and uncommon object, must remember that when the sensation was first impressed upon his mind, all other objects, ideas, and notions, and amongst the rest the notion of time, were for a while excluded. Of Time.

Succession of ideas gives the first conception of time.

No sensation, however, keeps possession of the whole mind after it has ceased to be new; nor can the most vigorous exertions long preserve any one idea from being driven off the stage by the succeeding train. Now this succession of ideas appearing and disappearing in their turns, is that which, when compared with the permanency of ourselves and other things, gives us our first and justest notion of time; for whilst we are thinking, or whilst a series of ideas is successively passing through our minds and vanishing, we know that we ourselves and the things around us exist; and this existence, or continuation of existence, commensurate with the train of our fleeting ideas, is what we call the duration of ourselves and the things around us.

We are aware that the first notions of time have been often said to be derived from motion as perceived by our senses in the objects around us. It is observed by Euclid, that "if there were no motion, there could be no sound, nor any sense of hearing." "He might have added," says the author of Ancient Metaphysics, "nor any other perception of sense. Further, without motion there would have been no visible world, nor generation or production of any kind here below; and, among other things, time could have had no existence." All this is certainly true; but that corporeal motion, though the original source of all our ideas, is not that which immediately suggests to us the notion of time, will be readily granted by him who considers that motion itself is perceived by us only when it excites or accompanies a constant succession of perceptions and ideas. Motion, when equable and very slow, such as that of the hour-hand of a common watch, is not perceived by us in its course; nor can we discover that the thing has moved at all, till after we have been sensible of the lapse of a considerable portion of what is commonly called time, when we discover that the hand of the watch has changed its place with respect to other objects which we know to be fixed. The same is true of motion remarkably quick: "Let a cannon ball," says Locke, "pass through a room, and in its way take with it any limb or fleshy parts of a man; it is as clear as any demonstration can be, that it must strike successively the two sides of the room; it is also evident that it must touch one part of the flesh first, and another after, and so in succession; and yet I believe nobody who ever felt the pain of such a shot, or heard the blow against the two distant walls, could perceive any succession either in the pain or sound of so swift a stroke."

The succession of ideas the measure of all other successions.

Of these two phenomena a satisfactory account may be easily given; from which we think it will at the same time be apparent, that the succession of the train of ideas in the mind is the measure and standard of all other successions. We know that the energy of mind which reviews a train of sensible ideas is of the very same kind with that which attends to a series of passing sensations; and therefore it is natural to suppose that we can pay attention to sensations and ideas passing with nearly equal velocities. But it has been shown, that every sensation remains in the mind or sensorium for a very short space after the object which excited it is taken away; whence it follows, that a body communicating to the organs of sense a series of similar impressions succeeding each other with remarkable

Of Time. rapidity, cannot possibly excite a train of similar and distinct sensations; because the effects of the first and second impressions not having vanished when those of the third and fourth arrive, the whole train of effects must necessarily coalesce into one uniform sensation. This reasoning is confirmed by experience. Similar sounds succeeding each other at considerable intervals are all distinctly perceived, and if the motion be accelerated gradually, it may be carried to a great degree of velocity before the sounds be confounded and coalesce into one. Sir William Herschel having, by means of a clock, produced sounds or clicking noises, which succeeded each other with such rapidity that the intervals between them were, as far as could be judged, the smallest possible, found that he could evidently distinguish one hundred and sixty of them in a second of time; but beyond that he could by no effort of attention distinguish one sound from another. The same philosopher tried another experiment on visible sensations. By means of the same handle and work of the clock, he caused a wheel in it to turn till it acquired the velocity of once in a second. He continued to increase the velocity, and observed it whilst revolving at the rate of twenty times round in thirteen seconds, and could still distinguish the teeth and spaces from each other; whence it appears, by a computation given at length, that he had two hundred and forty-six distinct visible sensations generated by equable motion in a second of time. The teeth of the wheel, he owns, were not so far visible as to show their shape distinctly, much less could they have been counted; but he very plainly distinguished the circumference to be divided into teeth and spaces; and he supposes that the same division might still have been seen though the motion had been a little faster, as far perhaps as two turns in a second, equal to three hundred and twenty sensations.[1] The reason why the division could not be seen whilst the wheel moved more rapidly than twice round in a second of time, was doubtless the continuance of that agitation in the brain from which each sensation proceeded, until a new impression caused a new agitation, which coalesced with the former and removed all distinction. Hence it is plain, that no external succession can be perceived which moves with a greater velocity than that of which the internal train of sensations and ideas is capable. On the other hand, an external succession which moves with less rapidity than that to which the internal flow of ideas may be reduced, either has not sufficient force to generate sensations at all, or the successive impressions from which the sensations proceed follow one another at such distances as to permit the natural train of ideas to intervene between them, and thus destroy the perception of the succession entirely.

To us, therefore, it seems evident that the constant and regular succession of ideas in the mind of a waking man is the measure and standard of all other successions; of which, if any one either exceeds the pace which our ideas are capable of, or falls short of it, the sense of a constant and continued succession is lost, and we perceive it not except with certain intervals of rest between. Hence it is not motion, but the constant train of ideas in our minds, that suggests to us our first notion of time, of which motion no otherwise gives us any conception, than as it causes in our minds a constant succession of sensations; and we have as clear a notion of time by attending to the train of ideas succeeding each other in our minds, as by a train of sensations excited by constant and perceptible motion.

That it is merely by comparing the permanent existence of things with the fleeting succession of ideas in our own minds that we acquire our notions of time, may perhaps be still more evident from the following narrative quoted by Dr Beattie,[2] from *L'Histoire de l'Académie Royale des Sciences pour l'Année* 1719. "A nobleman of Lausanne, as he was giving orders to a servant, suddenly lost his speech and all his senses. Different remedies were tried without effect. At last, after some chirurgical operations, at the end of six months, during all which time he had appeared to be in a deep sleep or delirium, his speech and senses were suddenly restored. When he recovered, the servant to whom he had been giving orders when he was first seized with the distemper, happening to be in the room, he asked whether he had executed his commission, not being sensible, it seems, that any interval of time, except perhaps a very short one, had elapsed during his illness." If this story be true, here was a man, who, by the train of ideas vanishing at once from his mind, lost the perception of what was to others six months of time; and had all mankind been in this state, the same portion of time would have been irrecoverably lost even to the annals of chronology.

We are aware of an objection to any inference which may be drawn respecting the present question, from the case of this nobleman. It may be said that he had lost, together with the perception of time, the perception of every thing besides; and that, therefore, motion may still be the cause from which a waking man derives his notions of time. But, in reply to this objection, we beg leave to ask, whether, if a ball had been put in motion on a table, and the nobleman had been told, that a body moved with the velocity of that ball would have been carried over so many thousand miles of distance during the time that he lay in a state of insensibility, he could from such information alone have formed any tolerable notion of the length of time during which he was insensible? He certainly could not, for want of a standard by which to measure the rapidity of the motion. He would, indeed, have known instantly that he had been insensible for a very considerable length of time, because he had the evidence of former experience that a body carried by perceptible motion over a great extent of distance would have generated in his mind a vast train of successive sensations; but unless he had attended this ball during part of its course, and compared with the permanency of other objects the series of sensations which it generated in his mind, he would not have been able to guess, with any thing approaching to accuracy, the length of time it would take to pass over a thousand miles. The same insensibility of duration happens to every man in sound sleep. From having notions of time, such as they are, formed in our minds, we never indeed suppose, however soundly we may have slept, that the moment at which we awake in the morning is contiguous to that in which we fell asleep at night. The reason is obvious. Every man has been awake whilst others were sleeping, and has known by experience, that if they had been awake likewise, a train of ideas would have passed through their minds which must have suggested to them the notions of time. Most men, too, have been frequently awake for entire nights, and have thus acquired a notion of time as going on incessantly, whether perceived by them or not; and this motion being closely associated with our ideas of night and morning, we inevitably suppose a portion of time to have elapsed between them, though unperceived by us in our sleep. But were a man to sleep without dreaming from Sunday night till Tuesday morning, and then to awake at his usual hour as marked on the clock, there are numberless instances on record to convince us, that he would not of himself suppose, nor perhaps be very easily persuaded, that more than one night had elapsed between the time of his falling asleep and the moment at which he awoke.

It being thus evident, that our conception of time is suggested by that comparison which we inevitably make of

[1] Watson's Treatise on Time.

[2] Essay on Truth.

Of Time. the existence of things permanent with the train of ideas incessantly passing through our minds, we may now perhaps be able to answer the question, "What is time?" It must of necessity be one of three things, viz. either the ideal succession itself; or a certain quality inherent in all objects; or merely the relation of co-existence between things that are permanent and the trains of fleeting ideas which succeed each other on the theatre of the imagination. It is not the first of these; for in every train of thought, the appearance of any one idea in the mind occupies no more of the extension of time, than a mathematical point occupies of the extension of distance. Ten thousand mathematical points added together would make no part of a line; and ten thousand ideas made to coalesce, if that were possible, would not occupy any part of that mode of duration which is called time. A point is the boundary of a line, but no part of it; the appearance of an idea in the mind is instantaneous; and an instant is the boundary, but no part of time. Hence it follows, that were every thing instantaneous, like ideas in a train, there could be no such thing as time, since nothing could be said to have, in that sense of the word, any duration. That time is not a quality inherent in all objects, is likewise obvious; for we have seen, that were ideas as permanent as objects, the notion of time could never have been acquired. Succession, although it does not itself constitute time, is essential to its existence; and were all motion to cease, and the attention of men to be immoveably fixed upon one invariable object or cluster of objects, time would likewise cease.

Time a mere relation of co-existence.

It remains, therefore, that time can be nothing else than the relation of co-existence apprehended between things that are permanent and those trains of fleeting ideas which incessantly succeed each other on the theatre of the imagination. Thus, whilst a man is steadily looking at one object, which, from its being common, does not occupy his whole mind, he may be conscious of a thousand ideas starting up in his imagination, and each in its turn vanishing the instant in which it appeared. Every one of these ideas had an existence as well as the object at which he is looking; but the existence of each of them was instantaneous and in succession, whilst the existence of the external object is permanent. The object, therefore, as contrasted with a train of ideas, is said to endure or to exist in time, whilst each idea is destitute of duration, and exists in no time.

Objections answered.

To this theory some objections occur, which it will be incumbent upon us to obviate. It may be said, that although each idea considered by itself is instantaneous, and occupies no time; yet the whole train, when taken together, without being compared with any thing external, is perceived to occupy a considerable portion of that mode of duration; and that, therefore, time itself must be something more than a mere relation between a fleeting succession of ideas and objects of more permanent existence. But how, we beg leave to ask, is the whole train perceived to occupy any portion of time? Is it not by being compared with our own existence? A man, whilst a train of ideas is passing through his mind, may be suddenly deprived of all his external senses, and then indeed it will be impossible for him to compare the fleeting existence of this internal succession with the more permanent existence of external things; but, whilst he thinks at all, he must be conscious of his own existence, and cannot avoid perceiving, that whilst his ideas pass in constant succession, each making an instantaneous appearance in his mind, he himself remains unchanged. Now, what is it that this perception suggests to the mind? Evidently nothing more than the relation of co-existence between a fleeting succession and a permanent object; for were it possible that the man could be deprived of memory as well as of his senses, and still have ideas succeeding each other in his mind, he would then think all objects equally fleeting; he would indeed be himself a mere succession of instantaneous distinct persons, and could have no notion whatever of time. His existence, though it should seem to endure half a century as estimated by others, must to himself appear to pass away like a flash of lightning. Of Time.

It may be still further objected to our theory, that time is measured by motion; and that it seems very absurd to talk of measuring a relation, especially a mere ideal relation, by a real external thing. In answer to this objection, which at first sight appears formidable, we beg leave to observe, that all relations are equally ideal; and that many of them may yet be said to be measured by real external things, with as much propriety as time can be said to be measured by motion. When a man wishes to ascertain the relation of quantity which one body bears to another, though he knows that such a relation has no other than an ideal existence, and cannot be conceived but in conjunction with the related bodies, he applies to them successively some common standard; and having discovered the relation which each bears to that, he compares the one relation with the other, and thus ascertains the relation sought. Just so it is with respect to motion measuring time. That which to each individual constitutes real time, is the relation of co-existence between the fleeting succession of his own ideas and other things of a more permanent nature. But a man has often occasion to ascertain the time of things external which fall not under the inspection of his senses; and in society all men have transactions with one another to be performed in some determinate portion of time, although there are not, perhaps, two men existing whose ordinary trains of thought flow with precisely the same rapidity. To remedy these inconveniences, it was necessary to invent some common standard, by means of which men might ascertain the duration of actions performed at a distance, and be able to keep appointments made with each other. The only standard proper for these purposes is such a constant and equable motion as has suggested a flux of perceptions common to all men in all ages and countries; and hence motions of the heavenly bodies have been universally made use of as the common regulators of time. These motions, however, do not constitute real and natural time, any more than a foot or a yard applied to two distant bodies constitutes the relation of quantity which these bodies bear to each other. They are merely stated measures, to be differently applied according to the different purposes which we have in view.

Thus, if a man in Europe wishes to know what would to him have been the real and natural time of an action performed in the East Indies, he has only to be told that it was co-existent, we shall suppose, with a diurnal revolution of the earth; and by comparing this common measure with his usual flow of thought, he can form some notion of the extent of that train of ideas which, had he been present, would to him have been successively co-existent with the action in question. But when persons have an appointment to keep, this common measure of motion must be differently, or rather partially, applied. In such cases, it is no part of their intention to compare their own existence with that of the whole train of ideas which may pass in the mind of each; for the result of such a comparison, which alone constitutes true and natural time, would not be the same in perhaps any two men; but their purpose is, to compare their own permanent existence only with that train of sensations which shall be excited in the mind by the perceptible motion of the sun, or any other body fixed upon, which moves equably; and such a train must consist of an equal number of instants in all men. Neither the sun nor the hour-hand of a common watch moves with such apparent rapidity as to keep pace with the internal flow of thought of which the most phlegmatic man is conscious. That these bodies move at all, is known only by

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their visible change of place during the lapse of a considerable portion of real time; and as there is in their course a certain number of places distinctly marked, to which alone it is agreed that the attention is to be turned, it is impossible that of time so computed two men can have different notions. Such time, however, is but partial; and the method of ascertaining it, when compared with that by which we ascertain real time, has a striking resemblance to that by which we ascertain the relation of partial quantity between two distant bodies. When it is our purpose to ascertain the relation of real quantity which one body bears to another, we apply the common standard to each in every dimension of length, breadth, and depth; but when we have no other view than to ascertain the relation of length which the one bears to the other, we apply the common standard to each in that dimension only. Just so it is with regard to real and partial time. When an individual wishes to ascertain what would to him have been the duration of any action which he did not see performed, he applies the common standard to the existence of that action, and to the usual flow of his own thoughts; but when two men talk of the duration of any action, or agree to meet upon such a day, they compare the existence of the action, or the distance intervening between the present moment and the day of meeting, only with that partial train of sensations which by the common standard is generated in an equal number, and in the same order, in the minds of both.

Time must have had a beginning.

It will be said, that if time be nothing more than a mere relation subsisting between trains of ideas or other fleeting objects, and things of a more permanent existence, and if the universe really had a beginning, either time must have had a beginning likewise, or the Deity cannot be immutable. We allow the force of the argument; but instead of an objection, we consider it as a confirmation of the truth of our theory. The Deity, who is immutable, exists not in time, but in eternity; and that these, though from the poverty of language they are both called modes of duration, are yet very different from each other, we shall endeavour to prove in the next chapter.

CHAP. VIII.—OF INFINITY AND ETERNITY.

Infinity and eternity.

As corporeal substance is certainly not infinite, and as the present material system has in itself every evidence of its not being eternal, it may seem strange, perhaps, to the reader, that we should treat of infinity and eternity amongst the adjuncts of body. But in modern metaphysics these words are used in a vague sense to denote the extent of space and time; and in this chapter it is our intention to do little more than ascertain their meaning, and to show, in opposition to some celebrated names, of what subjects they may not be predicated. There is a mathematical and a metaphysical infinity, which, although often confounded, ought to be kept distinct. In mathematics, extension is said to be divisible *in infinitum*, and number is sometimes considered as infinite; but in metaphysics these modes of expression are extremely improper. A positive and metaphysical infinite is that which has no limits, and to which no addition can be made; but it is obvious that there is no number which may not be enlarged, nor any positive idea of extension which has not limits, and which may not be either increased or diminished. The infinity of the mathematician is termed infinity of power, and that of the metaphysician absolute infinity. The first consists in this, that a being, however great or small it be supposed, may still be conceived to possess more greatness or minuteness than we can form an idea of, even after the utmost stretch of human thought. Thus, when it is said, that all extension as such is infinitely divisible, it is not meant that every extended substance contains an infinite number of real parts; for then the parts of an inch would be equal to those of a league; but the meaning is, that in ideal extension we can never reach the end of ideal division and subdivision. In like manner, when it is said that number is infinite, the meaning is not that any positive number is without limits, or the possibility of increase, but that we might go on for ever, adding unit to unit, without approaching nearer to the end of the process. If, therefore, the mathematician would speak properly, and without the affectation of paradox, he ought to say that all extension, as such, is indefinitely divisible, and that unit might be added to unit without end; but these phrases suggest notions very different from that of a metaphysical infinite, which is something positive to which nothing can be added.[1]

Space and time.

That there is something positively infinite, has been very seldom questioned; but it has been warmly disputed amongst metaphysicians what subjects are infinite. Dr Clarke and his adherents have contended that space and time are real things; that they are bodies of necessary existence; that the former impresses us with the idea of its infinity, and that the latter is positively eternal. "Time and space," says Dr Clarke,[2] "are the *sine qua non* of all other things, and of all other ideas. To suppose either of them finite, is an express contradiction in the idea itself. No man does or can possibly imagine either of them to be finite; but only either by non-attention or by choice he attends perhaps to part of his idea, and forbears attending to the remainder. They who suppose space to be nothing but a relation between two bodies, are guilty of the absurdity of supposing that which is nothing to have real qualities; for the space which is between two bodies is always unalterably just what it was, and has the very same dimensions, quantity, and figure, whether these or any other bodies be there or anywhere else, or not at all; just as time or duration is the same, whether you turn your hour-glass or no, or whether the sun moves or stands still, or whether there was or was not any sun, or any material world at all. To set bounds to space is to suppose it bounded by something which itself takes up space, and that is a contradiction; or else that it is bounded by nothing, which is another contradiction. To suppose space removed, destroyed, or taken away, amounts to the absurd supposition of removing a thing away from itself; that is, if in your imagination you annihilate the whole of infinite space, the whole of infinite space will still remain; and if you annihilate any part of it, that part will still necessarily remain, as appears by the unmoved situation of the rest; and to suppose it divided or divisible amounts to the same contradiction."

The absurdity of considering space as a real external thing has been already evinced in Chapter IV. where it was shown how we acquire the notion, and what kind of notion it is. Space, as was there observed, may be conceived either as the mere absence and possibility of body; or as ideal extension, united to and inhering in an ideal substratum. Taken in the former sense, it is an object of pure intellect; in the latter it is an idea or form in the imagination. That the absence of body or matter is the *sine qua non* of all other things, and all other ideas, Dr Clarke was not disposed to affirm, when he made the divine substance to pervade every material atom in the uni-

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[1] Aristotel. *Phys. Auscult.* lib. ix. cap. ix. page 492.

[2] Demonstration of the Being and Attributes of God, and Correspondence with a Gentleman of Gloucestershire.

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verse; and to talk of the absence of body being infinite is a palpable contradiction, unless Berkeley's doctrine be true, that the material world has no existence. To say that the possibility of matter is infinite, is to use language which has *no* other meaning than that, however far the material world be on all sides extended, its extension may *still* be conceived greater and greater *in infinitum*. This is a position which no philosopher, ancient or modern, has ever denied; but it is so far from implying that we have a positive idea of the infinity of the material world, or of any adjunct of the material world, that it is absolutely inconsistent with such infinity. Whatever is capable of perpetual increase must certainly have limits, and every new addition is the limit of that to which the addition was made.

Neither space nor time can be positively infinite.

Taken in the second acceptation as an ideal extension united with an ideal substratum, space is so far from being infinite in any sense of the word, that we will venture to assert no man ever contemplated such a form in his own imagination, without conceiving it to be bounded. Of this, at least, we are certain, that when we have attempted to frame a positive idea of pure space, it has not been in our power to divest that idea of limits. Those who can frame in their minds real and positive ideas wholly abstracted from every individual object, may indeed perform in this way many feats above our abilities; but as we possess no such powers of abstraction, every thing which we can call an idea is limited in the same manner that the object itself is limited from which the idea was derived. Thus the largest expansion that we ever beheld is that of the concave hemisphere; and when we try to form the largest positive idea of pure space, all that we can do is to figure to ourselves that concave empty of body. We may, indeed, suppose its diameter to be either a million or ten thousand millions of miles, and we may go on enlarging it *in infinitum;* but when we return from this process of intellect to the contemplation of the ideal forms of the imagination, none of these forms appears to us larger or more extended than the hemisphere, which is the object of sense, and they all appear to be bounded, and bounded in the very same way.

With respect to the eternity of time, again, we think Dr Clarke equally mistaken as with respect to the infinity of space. Of time, indeed, we cannot, properly speaking, have any idea or mental form. Time, as we have seen, is a mere relation, and is in itself the creature of the mind, which has no external *idiatum*. It is suggested, however, by the fleeting succession of our ideas, compared with the more permanent existence of other objects; and therefore succession is essential to it. But nothing which has parts, whether co-existent or in succession, can be positively infinite. For, in an infinite series of successive generations of men, for instance, there will be several infinites that are parts of one another, and by consequence one greater than another which, as has been well argued,[1] is an express contradiction, since the greater must necessarily bound the less, and exceed its limits by so much as it is greater than it; that is, must make it not infinite. Infinite generations contain an infinitely greater infinity of particular men. An infinite number of men must have twice as many hands, and ten times as many fingers, and so on. Infinite time has an infinity of ages; these a much greater infinity of years, days, hours, &c. Space likewise, according to Dr Clarke, has three dimensions, all infinite. It must therefore contain an infinity of surfaces, an infinitely greater infinity of lines, and a still infinitely greater infinity of physical points. The case is the same in number itself, which, if we suppose it to contain an absolute infinity of thousands (and we may as well do that as imagine it to comprehend an infinity of units), will contain ten times as many hundreds, fifty times as many scores, and so on. All this is only the indefiniteness of number, which we in vain attempt to turn into a positive infinite, with which it is totally incompatible. For let us add one to any of these infinite series of generations, ages, lines, or numbers, which we know to be always in our power, and if it was absolutely infinite before, here is one more than infinite. If it only becomes infinite now, then one finite added to another finite makes infinity. If it be no larger after the addition than it was before, then one part added to another adds nothing; all which are absurdities. The same will appear if we subtract a part from this supposed absolute infinite, which may be done in any of the before-mentioned subjects, as well as in every thing which admits of parts, or may be taken in pieces by the mind.

Of Infinity and Eternity.

The usual reply to this is a *petitio principii.*

To this kind of reasoning Dr Clarke replies as follows: "To endeavour to prove that there cannot possibly be any such thing as infinite time or space, from the impossibility of an addition of finite parts ever composing or exhausting an infinite, or from the imaginary inequality of the number of years, days, and hours, that would be contained in the one, or of the miles, yards, and feet, that would be contained in the other, is supposing infinites to be made up of numbers of finites; that is, it is supposing finite quantities to be aliquot or constituent parts of infinite, when indeed they are not so, but do all equally, whether great or small, whether many or few, bear the very same proportion to an infinite, as mathematical points do to a line, or lines to a superficies, or as moments do to time, that is, none at all. No given number or quantity can be any aliquot or constituent part of infinite, or be compared at all with it, or bear any kind of proportion to it, or be the foundation of any argument in any question concerning it."

If it be indeed true, and it is that for which we contend, that no given number or quantity can be any aliquot or constituent part of infinite, or be compared at all with it, then it undeniably follows, not that miles, yards, and feet are no constituent parts of space, or years, days, and hours constituent parts of time, but that space and time cannot possibly be positive infinites. This, we say, follows undeniably; for nothing is more evident than that all quantities of the same kind, from the largest to the least, bear a certain proportion to each other; and upon the supposition that space is a real extending thing, miles, yards, and feet are included in it, and bear to it the relation of parts to a whole. The same is true of time, days, and hours. To affirm, for no proof is offered, that all finite quantities, whether great or small, whether many or few, do equally bear the very same proportion to an infinite, as mathematical points do to a line, or as moments do to time, is plainly to beg the question, "that space considered as a real extended thing is infinite," and to beg it, too, in opposition to the common sense and reason of mankind. Mathematical points we all know to be nothing real, but merely negations of extension; but supposing space to be something real and extended, can any man persuade himself that a mile or a million of miles of this space is likewise a mere negation of extension? With him who can bring himself into this persuasion, we do not pretend to argue. He is possessed of faculties, whether true or false, of which we are destitute.

That finite quantities, whether these be great or small, do

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[1] Dr Law's Inquiry into the Ideas of Space, Time, Immensity, and Eternity. See also the same writer's translation of King's Origin of Evil.

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all equally bear the same proportion to an infinite in power, is indeed true; but it is no great discovery; for such an infinite, as we have seen, is nothing but the continued possibility of repeating the same mental process of addition or multiplication; and he who can go on for ever adding, in his own imagination, foot to foot, or hour to hour, will find it equally easy to add, in the same manner, league to league, or age to age. If he can perform the one operation, he must likewise have power to perform the other; and he cannot but perceive that it is as impossible to come to an end of adding league to league, or age to age, as of adding foot to foot, or hour to hour; but then he must know that these leagues, and feet, and ages, and hours, are not real external things, but mere ideas and notions in his mind. If such powers of ideal multiplication and addition be what Dr Clarke means by the ideas of space and time, it is indeed a contradiction to suppose either of them limited; for that would be to suppose our powers different from what we know them to be by consciousness and experience. But to confound powers with the objects of those powers, is certainly very inaccurate; and to suppose, because we can go on for ever adding one portion of ideal space or time to another, that therefore our ideas of space and time are in themselves positively infinite, is a contradiction; for to an idea positively infinite it is obvious that nothing can be added. Either, therefore, space and time do not impress us with the ideas of their positive infinity; or we cannot have the power of adding league to league, and age to age, without end.

"But," says Dr Clarke, "to suppose space removed, destroyed, or taken wholly away, amounts to the absurd supposition of removing a thing from itself; that is, if in your imagination you remove the whole of space, the whole of space will still remain." True, every man has ideas of space treasured up in his imagination, which the sound of the very word space will at all times bring into his immediate view; and whilst he has such ideas, it is impossible that he should not have them; which is all the mystery of the matter, and amounts to nothing more than that a thing cannot be and not be at the same instant. When the doctor affirms, that if "you annihilate any part of space, that part will necessarily remain, as appears by the unmoved situation of the rest," we are not certain that we perfectly understand him. A man may surely think of a cubical inch without also thinking of a foot or a yard; and he may suppose the inch taken away from the foot or the yard, and these ideal quantities so much lessened by the subtraction. But if the doctor be here again confounding the powers of the mind with the positive ideas of space, the sentence when explained will be found to contain nothing to his purpose. Every man has the power of contemplating in idea millions of miles, and millions of ages, and of adding mile to mile, and age to age, without end; and if he try to deprive himself of any part of this power, or to fix a limit to the mental process of addition, he will find that in spite of himself his imagination will ramble beyond the limit assigned, and that he has attempted an utter impossibility. This, however, is so far from being a proof that his ideas of space and time are positively infinite, that, as we have already observed, it is a proof of the contrary.

Clarke's notion of space and time.

But, says this great man and his followers, "space and time are the *sine qua non* of all other things and all other ideas. The supposal of the existence of any thing whatever includes necessarily a presupposition of the existence of space and time;" and, therefore, if there be any thing infinite and eternal, space and time must likewise be so.

There are things which have no relation to either.

To every corporeal substance, and every idea of such substance, space and time are indeed necessary; for every body has extension and duration, and every idea of a particular body, being nothing but a secondary perception in the imagination or the memory, must have the same relation to imaginary extension that the object from which it was derived has to extension which is real. Every idea, too, which remains in the imagination whilst a train of other ideas passes successively in view, or whilst external things are perceived to change, has real time. But will any man pretend that consciousness, our notion of power, our acts of willing, or even tastes, sounds, and smells, are extended, or that the supposition of their existence necessarily implies a presupposition of the existence of space? We acquire our ideas of extension and of space by means of our senses of touch and sight; and we learn from experience that things external and extended are the causes of our sensations of taste, and sound, and smell. The effects are in our minds closely associated with the ideas of their causes; and it is not perhaps easy to think of a particular sound, taste, or smell, without at the same time thinking of the object by which it was first excited in the mind; but if we had been originally formed with the powers of consciousness, thinking, and willing, and with no other senses than those of tasting, smelling, and hearing, it is obvious that we never could have had the idea of space; and therefore, that idea cannot possibly be necessary to the presupposition of every thing else. To consciousness, thinking, and willing, space is so far from being necessary, that we cannot perceive any the most distant relation between them. It is not more difficult to conceive a part greater than the whole, than it is to conceive an ell of consciousness, of thought, or of will; nor is it in the power of any man to make space and sweetness coalesce in his mind so as to form of these two simple ideas one complex conception. The very reverse is the case with respect to the objects of sight and touch. The idea of every thing which we see and handle necessarily coalesces in the mind with the idea of space, nor can we possibly separate the one from the other; but the things which we see and handle are neither infinite nor capable of infinity.

With respect to time, the same observations will be found to be as applicable as with respect to space. Whatever is liable to change exists in time, and cannot be eternal; but if there be any immutable being who views at once all things which to us are past, present, and to come, the existence of such a being is not commensurable with time. That such a being is possible, no man can doubt who reflects, that if we had one permanent idea invariably in the mind, we should never have acquired the notion of succession or of time; and that if there were actually no change in nature, there could not possibly be in nature any such thing as time. Every man, therefore, who can conceive existence without change must be convinced, that the supposition of the existence of any thing whatever does not necessarily include the presupposition of the existence of time, and that there may be an eternity distinct from time, as well as an infinity distinct from space; nay, that that which is properly infinite and eternal cannot possibly occupy either space or time.

Infinity and eternity.

If it be asked, What kind of infinity and eternity they are which have no relation to space and time? Cudworth, treading in the footsteps of the ancients, has long ago answered, that they are "absolute perfection and necessary existence." For, according to him, infinite understanding and knowledge are nothing else but perfect knowledge, which has in it no defect or mixture of ignorance, but knows whatsoever is knowable. In like manner, infinite power is nothing else but perfect power, which has in it no defect or mixture of impotency; a power which can do every thing which is possible or conceivable. Lastly, infinity of duration, or eternity, is really nothing else but perfection, as including in it necessary existence and immutability; so that it is a contradiction to suppose such a being to have had a beginning, to cease to be, or to suffer or be affected by any change whatsoever. And because infinity is perfec-

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tion, therefore, whatever includes in its idea or essence any thing of imperfection, as every positive idea of number, corporeal magnitude, and successive duration evidently does, cannot be truly and properly infinite.

The idea of succession.

It must indeed be confessed, that the idea of succession so insinuates itself into our usual ideas of existence, and is so closely connected with the existence of all finite beings, that we find it extremely difficult to imagine the eternal existence of God any otherwise than as an eternally continued series or succession. Our constant conversation with material objects, and the associations thence arising, make it almost impossible for us to consider things abstracted from time and space; yet we have the evidence of experience and consciousness that an idea may be conceived without relation to space and time, and that space and time cannot be made to coalesce with some of our notions. The same must be true with respect to infinity and eternity; for we have seen that neither space, nor time, nor any thing else which consists of parts, whether continuous or successive, can be supposed to be positively infinite, as the supposition implies the most palpable contradiction. But that there may be perfect power, perfect knowledge, and permanent invariable existence, is so far from implying any contradiction, that even we, whose faculties are all so very limited, can yet make some advances towards the conception of such perfections. Thus, every man of common understanding knows that some things are in themselves possible, and others impossible, to be performed by any power. Of these possibilities and impossibilities a philosopher knows more than an illiterate man; and one philosopher knows more than another. An intellect more perfect knows more of them than any man; and that intellect which knows them all must be absolutely perfect, and incapable of improvement, because it knows every thing which is to be known. The same is true of perfect power; but we shall treat of real infinity and eternity more at large when we come to demonstrate the being and attributes of God. At present it is sufficient to have shown that nothing can be positively infinite but a being absolutely perfect, which can produce all things possible and conceivable, and upon which all other things must depend.

PART III.

OF MINDS AND THEIR POWERS.

CHAP. I.—OF MIND IN GENERAL.

Mind distinguished from body.

The science of metaphysics comprehends every thing into the existence, the nature, or the causes of which any inquiry may be made. But all things of which we have any notion or idea may be divided into mind and body, with their various powers, and qualities, and adjuncts. By body is meant that which is solid, extended, inert, and divisible; and its several adjuncts are space, motion, number, and time. The only mind with which we are intimately acquainted is our own; and we know that it is possessed of the powers of sensation, perception, retention, consciousness, reflection, reason, and will. These are totally different from extension, solidity, divisibility, and motion; and therefore it is proper to distinguish the being of which they are powers by another name than that of body.

Minds of different orders.

Of bodies there are various kinds, possessing various sensible qualities; and hence from analogy it is reasonable to conclude, that there may be various classes of minds endowed with different kinds or degrees of power. For this indeed we have much stronger evidence than that of analogy. Brute animals evidently possess the powers of perception and spontaneity, with some degree of consciousness; but as they do not appear to reflect upon their own conduct, or to have their actions influenced by motives, their minds are inferior to ours, although still perfectly distinct from mere extended, inert, and divisible substances. Mind, therefore, considered with respect to its powers, is evidently different from body, considered with respect to its qualities. This is indeed a truth which has seldom or never been controverted; but it has been long and warmly disputed, whether mind and body be not both composed of the same first matter.

Hypothesis of Hobbes.

Hobbes supposed that every material atom is endowed with the faculty of sensation, but that for want of memory each sensation is momentaneous, being instantly and wholly effaced as soon as its cause is removed. Though this hypothesis is too absurd to require a formal and laboured confutation, it may not be improper to observe, that, if it were true, the hairs of a man's head would feel extreme pain when pinched by the hot iron of the hair-dresser, and that the nails of his fingers would be severely tortured when under the operation of the knife or the file.

Other hypotheses.

Others, again, have supposed that each atom of matter has a tendency towards sensation and perception; and that when a sufficient number of these atoms are brought together in a certain order, the united tendencies produce the actual powers which distinguish mind from gross body. This supposition is, if possible, more absurd than that of Hobbes. Sensation and perception are of such a nature, that a mere tendency towards them is inconceivable. A thing must either be sensible and percipient, or insensible and inert; there is evidently no medium. Or if we could suppose each individual atom to have a tendency towards sensation, it would by no means follow that a number of such atoms brought together in any possible order would become one sentient, thinking, and active being. A number of bodies laid upon an inclined plane have each a tendency to roll downwards; but if the declivity of the plane be not such that their separate tendencies may overcome the resistance opposed to each individual body by friction, the united tendencies of all these bodies when brought together will not be sufficient to overpower the resistance of their united frictions. It is just so with respect to sensation and perception. If the tendency of one atom cannot overcome one degree of inertness, the tendency of a thousand atoms will not overcome a thousand degrees of the same inertness.

Only two opinions at present on the subject.

We have just mentioned these absurd suppositions, that our article might be complete; but it is proper to inform the reader, that, so far as we know or are aware, neither of them has for many years been maintained by any philosopher of eminence either at home or abroad. The opinions on this subject which at present divide the republic of letters are two, and these alone are worthy of examination. One party maintains that perception, memory, reason, and will, &c. are the powers of a being which must be immaterial and indivisible; the other alleges, that as we know nothing of these powers but from our own consciousness, and as we can trace them in ourselves to the brain and no farther, we have no reason to suppose that they are the powers of any substance distinct from matter. Both parties, however, distinguish that which in man is the subject of thought from his external organs of sense, and agree to call it by the name of *mind*; although the one considers it as composed of the same first matter with the dust of the ground, whilst the other believes it to have no property whatever in common with that matter.

Were we to adopt some of the ancient methods of philosophizing, this important question might soon be decided. A most respectable writer, who has laboured to restore the metaphysics of Plato and Aristotle, attempts to confute the materialists, by laying down what they must think arbitrary definitions of mind and matter, and then show-

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ing that the one is not the other. "In all the parts of the material world," says he, "there is a perpetual motion; for the celestial bodies move constantly in one respect or another, and all here below is in a continual vicissitude of generation and corruption, which cannot be without motion. Now, where there is motion, there must be something that moves. What is moved I call *body;* what moves I call *mind.*" From this definition he undertakes to prove that mind must be immaterial. "That there is a relation between moving and being moved," says he, "nobody can deny; and the relation is no other than that of action and passion. But the nature of relation is such, that it must necessarily be between two things at least; and it is further necessary, that the two things related should exist together. Hence, if there be that which moves, there must be a different thing that is moved; and wherever the one is, the other must necessarily be; so that nothing can move itself. This being established, I say that what moves must be either material or immaterial; for the one of these being the negation of the other, there can be no middle betwixt them, because a thing must necessarily be or not be. If then it be immaterial, there is an end of the question; but if it be said to be material, then I say that it must be moved itself before it can move any thing else, for it is only in that way that body can move body. If then it must be first moved itself, but cannot itself move itself, what is it that moves itself? If it be answered that it is another material mover, then I repeat the same question, to which the same answer must be given; and so we have an infinite series of material movers, without any beginning or principle of motion. Now this is absurd, and contradictory to this first principle of natural philosophy, admitted by all philosophers ancient and modern, that *nothing can be produced without a cause.*"

The proper method of investigation.

For the immateriality of the human mind, and of every being endowed with the powers of perception and thought, the learned writer has better arguments; but it is upon this chiefly that he rests his persuasion, that mind is the only mover in the universe. It is needless to observe, that in the very definitions and axioms upon which this reasoning is built, the thing to be proved is taken for granted; for if it be self-evident that what moves is, in the author's sense of the word, mind, that what is moved is body, and that nothing can move itself, all reasoning on the subject is superfluous. This, however, is so far from being self-evident, that a materialist may reply, that "every animal moves itself, and yet every animal is nothing more than a system of matter." This position, whether true or false, can neither be proved nor confuted by arguments *a priori* founded on general definitions. That animals move themselves, and that to the senses they appear to be nothing else than systems of matter, are facts which cannot be controverted. If we would know whether they have in them a principle of motion which is not material, we must submit to the laws of induction, and, by investigating the essential qualities of matter, endeavour to ascertain whether a material system can be rendered active. That we ourselves have active powers, we know by the most complete of all evidence, our consciousness of their energies; and it has been already shown, that such powers as we experience in ourselves cannot exist but in a subject possessed of will and understanding. The question, therefore, to be first decided between the materialists and immaterialists is, whether the powers of consciousness, understanding, and will, can result from the particular organization of a system of matter. If they can, then we have no reason to attribute them in man to any other source. If these powers appear necessarily to require an immaterial principle for their support, it will probably be granted that an immaterial principle is the source of every power and every motion in the universe; and the doctrine of mind, in the strictest sense of the word, will be sufficiently established.

Of the Substance of the Human Mind.

CHAP. II.—OF THE SUBSTANCE OF THE HUMAN MIND.

Arguments for the immateriality of the human mind.

The most celebrated materialist of this, or perhaps of any other century, was Dr Priestley, who having in his own imagination divested matter of solidity, and reduced it to mere centres of attraction and repulsion, observed, that "if one kind of substance be capable of supporting all the known properties of man, that is, if those properties have nothing in them that is absolutely incompatible with one another, we shall be obliged to conclude (unless we openly violate the rules of philosophizing, which will not authorize us to multiply causes or kinds of substance without necessity), that no other kind of substance enters into his composition; the supposition being manifestly unnecessary, in order to account for any appearance whatever. All the properties that have hitherto been attributed to matter may be comprised under those of attraction and repulsion. Besides these, man is possessed of the powers of sensation or perception, and thought. But if, without giving the reins to our imaginations, we suffer ourselves to be guided in our inquiries by the simple rules of philosophizing above mentioned, we must necessarily conclude that these powers also may belong to the same substance that has also the properties of attraction, repulsion, and extension, which I as well as others call by the name of *matter.* The reason of the conclusion is simply this, That the powers of sensation or perception, and thought, as belonging to man, have never been found but in conjunction with a certain organized system of matter; and therefore that those powers necessarily exist in, and depend upon, such a system. This at least must be our conclusion, till it can be shown that these powers are incompatible with the other known properties of the same substance; and for this I see no sort of pretence."

This is what Dr Priestley has called the proper and direct proof that the sentient principle in man is the material substance of the brain; and he enforces it by the following observations: "Had we formed a judgment concerning the necessary seat of thought by the circumstances that universally accompany it, which is our rule in all other cases, we could not but have concluded that in man it is a property of the nervous system, or rather of the brain; because, as far as we can judge, the faculty of thinking, and a certain state of the brain, always accompany and correspond to one another, which is the very reason why we believe that any property is inherent in any substance whatever. There is no instance of any man retaining the faculty of thinking when his brain was destroyed; and whenever that faculty is impeded or injured, there is sufficient reason to believe that the brain is disordered in proportion; and therefore we are necessarily led to consider the latter as the seat of the former. Moreover, as the faculty of thinking in general ripens and comes to maturity with the body, it is also observed to decay with it; and if, in some cases, the mental faculties continue vigorous when the body in general is enfeebled, it is evidently because in those particular cases the brain is not much affected by the general cause of weakness. But, on the other hand, if the brain alone be affected, as by a blow on the head, by actual pressure within the skull, by sleep, or by inflammation, the mental faculties are universally affected in proportion. Likewise, as the mind is affected in consequence of the affections of the body and brain, so the body is liable to be reciprocally affected by the affections of the mind, as is evident in the visible effects of all strong passions, hope or fear, love or anger, joy or sorrow, exultation or despair. These are certainly irrefragable argu-

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ments, that it is properly no other than one and the same thing that is subject to these affections, and that they are necessarily dependent upon one another. In fact, there is just the same reason to conclude, that the powers of sensation and thought are the necessary result of a particular organization, as that sound is the necessary result of a particular concussion of the air. For in both cases equally the one constantly accompanies the other; and there is not in nature a stronger argument for a necessary connection of any cause and any effect. To adopt an opinion different from this, is to form an hypothesis without a single fact to support it."

Although the ingenious author thinks, that if there be any foundation for the established rules of philosophizing, this reasoning ought to be conclusive, he yet subjoins, for the greater satisfaction of his readers, some additional arguments, or rather, as he says, distinct illustrations of the great argument. They are as follow:

1. "That the faculty of thinking necessarily depends, for its exercise at least, upon a stock of ideas, about which it is always conversant, will hardly be questioned by any person. But there is not a single idea of which the mind is possessed but what may be proved to have come to it from the bodily senses, or to have been consequent upon the perceptions of sense. The notion, therefore, of the possibility of thinking in man, without an organized body, is not only destitute of all evidence from actual appearances, but is directly contrary to them; and yet these appearances ought alone to guide the judgment of philosophers.

2. "The only reason why it has been so earnestly contended for, that there is some principle in man that is not material, is, that it might subsist, and be capable of sensation and action, when the body is dead. But if the mind was naturally so independent of the body as to be capable of subsisting by itself, and even of appearing to more advantage after the death of the body, it might be expected to discover some signs of its independence before death, and especially when the organs of the body were obstructed, so as to leave the soul more at liberty to exert itself; as in a state of sleep or swooning, which must resemble the state of death, in which it is pretended that the soul is most of all alive, most active, and vigorous. But, judging by appearances, the reverse of all this is the case.

3. "If the mental principle was, in its own nature, immaterial and immortal, all its particular faculties would be so too; whereas we see that every faculty of the mind without exception is liable to be impaired, and even to become wholly extinct, before death. Since, therefore, all the faculties of the mind, separately taken, appear to be mortal, the substance or principle in which they exist must be pronounced to be mortal too.

4. "If the sentient principle in man be immaterial, it can have no extension; it can neither have length, breadth, nor thickness; and consequently every thing within it, or properly belonging to it, must be simple and indivisible. Let us now consider how this notion agrees with the phenomena of sensation and ideas. It will not be denied, but that sensations or ideas properly exist in the soul, because it could not otherwise retain them, so as to continue to perceive and think after its separation from the body. Now, whatever ideas are in themselves, they are evidently produced by external objects, and must therefore correspond to them; and since many of the objects or archetypes of ideas are divisible, it necessarily follows, that the ideas themselves are divisible also. But how is it possible that a thing (be the nature of it what it may) that is divisible should be contained in a substance, be the nature of it likewise what it may, that is indivisible? If the archetypes of ideas have extension, the ideas which are expressive of them, and are actually produced by them according to certain mechanical laws, must have extension likewise; and therefore the mind in which they exist, whether it be material or immaterial, must have extension also. But how any thing can have extension and yet be immaterial, without coinciding with our idea of mere empty space, I know not."

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The arguments answered.

To the argument, which is here chiefly insisted upon as being agreeable to the established rules of philosophizing, a very able reply has been made, which we shall give in the words of its elegant and spirited author. But before we attempt to dig up the foundation of the doctor's system, it may not be improper to demolish, if possible, the additional buttresses by which it is strengthened. An experienced general, before he storms a citadel which he knows to be strongly fortified and skilfully defended, will take care to raze every less important redoubt from which the enemy might annoy him in his rear.

Because the faculty of thinking in general ripens, comes to maturity, and decays with the body, and the body, on the other hand, is affected by the affections of the mind, Dr Priestley affirms that we have the same reason to conclude, that the powers of sensation and thought are the necessary result of a particular organization, as that sound is the necessary result of a particular concussion of the air. This argument is conclusive only upon the supposition that there is no positive evidence whatever of the immateriality of the being which is the subject of thought. If the other reasonings for the materiality or immateriality of the mind be of equal weight, this argument ought doubtless to turn the balance; but if there be the smallest preponderancy in behalf of the immaterialists, it is a mere begging of the question to attempt to counteract it by any inference which can be drawn from the mutual affections of the body and mind. If two such heterogeneous beings as an immaterial mind and an organized body can be supposed united in one person, they must necessarily affect each other; and to affirm, on account of this reciprocal affection, that they are one and the same, is equally absurd as to say that an electrician and his apparatus are one and the same. Dr Priestley himself did not at first perform his electrical experiments with so much ease as after he had acquired facility by long practice, nor could he even yet perform them so neatly with a bad as with a good apparatus.

That which the doctor calls the first illustration of his argument might be admitted, and the force of the argument itself be consistently denied. Some kind of organized body may be necessary to the mind as an instrument without which it could not exert its faculties; but it would certainly be rash to infer that the mind must therefore be a system of matter. An anvil and a hammer are necessary to the exercise of the blacksmith's craft; but what would be thought of him who should from this fact conclude, that the blacksmith himself must be a system of iron. This, therefore, instead of illustrating the great argument, appears to be wholly foreign to the question in debate; and it has in fact been admitted by Dr Price,[1] and thousands of others who reject the doctrine of materialism, as an impious absurdity. The second illustration, however, is more to the purpose; and as it is not new, we shall give it an old answer.

Why do not we perceive external objects in our sleep or in a swoon? "Because," says Mr Wollaston,[2] "the passages are become impracticable, the windows shut, and the nerves, being obstructed, or somehow rendered for the

[1] Correspondence with Dr Priestley.

[2] Religion of Nature Delineated.

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time useless, can transmit no information to it. Why, however, does it not reason and think about something or other? Because all the marks by which things are remembered being for the present choked up or disordered, the remembrance of those objects about which it is wont to employ itself, and even of the words (or other signs) in which it uses to reason, and to preserve the deductions and conclusions it makes, are all suspended, at least for the time; and so its tables being covered, its books closed, and its tools locked up, the requisites for reasoning are wanting, and no subject offers itself to exercise its thoughts, it having yet had little or no opportunity to take in higher objects and more refined matter for contemplation. And, to conclude, if it be demanded, why any one should imagine that the soul may think, perceive, act, after death, when it doth not do this in sleep, &c.? The answer is, because those enclosures and impediments which occasioned the forementioned intermissions, and those great limitations under which it labours at all times, will be removed with its enlargement out of the body. When it shall in its proper vehicle be let go, and take its flight into the open fields of heaven, it will then be bare to the immediate impressions of objects; and why should not those impressions which affected the nerves, that moved and affected the vehicle and soul in it, affect the vehicle immediately when they are immediately made upon it, without the interposition of the nerves? The hand which feels an object at the end of a staff, may certainly be allowed to feel the same much better by immediate contact without the staff." Nor was the opinion, that the soul is united to some fine vehicle, which dwells with it in the brain, and goes off with it at death, peculiar to Mr Wollaston. It was thought extremely probable by Dr Hartley, and shall afterwards be shown to have been a very ancient opinion; but we do not quote it at present as either well or ill founded, but only as sufficient, in conjunction with the reasoning of its author, to obviate the force of Dr Priestley's second illustration of his argument for the materiality of mind, provided the argument itself be not more powerful than any which the immaterialists can bring against it.

The doctor's third illustration we have already obviated, when we accounted for the mind and the body mutually affecting each other; and we might refer to Dr Price's answer to the fourth, as being, in our opinion, a full confutation of it. But as that author's notions of mind and ideas differ in some respects from our own, we shall examine this objection to the doctrine of the immaterialists, upon principles which Dr Priestley would perhaps have been more inclined to admit.

That the sentient principle in man, if it be immaterial, can have no extension, is a truth which, we think, cannot be controverted; and if so, every thing in that principle must be simple and indivisible. Thus far we agree with Dr Priestley; but with respect to what follows we differ from him entirely. The agitation in the brain, which is the immediate cause of sensation, must indeed correspond to the impression *ab extra* by which it is produced, and therefore must have the property of extension; but that agitation, whatever it be, is not itself sensation, any more than a bludgeon is a blow, or a sword is a wound. Dr Priestley, indeed, in answer to Dr Price, affirms that, according to Hartley's theory, ideas are only vibrations in the brain; but whoever shall take the trouble to examine that theory himself, will not find that its author ever advances such an opinion, or considers vibrations as any thing more than the instruments by which sensations and ideas are excited in the sentient principle. A real and proper idea, as we have often repeated, is nothing else than a fainter sensation; but no sensation, from whatever cause it may proceed, is itself extended; nor could we, without memory, the reasoning faculty, and the power of local motion, have acquired from mere sense any notion of extension at all. (See Sect. III. Chap. I. Part I.) Sensations and ideas are those appearances, if we may say so, which vibrations or some other motion in the brain excite in the mind; but a half appearance is an absurdity. A man may view half a tree with his eyes, and he may contemplate the idea of half a tree in his mind, but he cannot have half a view or half an idea of any thing. Sensations and ideas result from the mutual agency of the brain and sentient principle upon each other; and if the agency of the brain be vibration, more of it may vibrate at one time than at another; but surely the mere relation between its agency at any time and the agency of the mind, can neither have extension nor be divisible, for who ever thought of extending or dividing relations? On this subject it is extremely difficult to write with perspicuity and precision, and what we have said may very possibly be misunderstood. Our notion is to our own mind clear and determinate; but language, which was not invented by metaphysicians, wants words in which it may be properly expressed. Perhaps the reader may understand what we mean, when we say that a sensation or an idea is the instantaneous effect of the mutual agency of the brain and sentient principle. Of this we think every man, by a little attention, may be perfectly convinced, though it may be impossible ever to discover the precise nature of this agency; and if so, it is plain that sensations and ideas cannot be divided, for no instantaneous effect of any kind is divisible. A sensation, and of course a simple and original idea, neither has extension itself, nor suggests the notion of extension *ab extra*. By running the hand or any other member along a solid body, we feel continued resistance; this feeling, or the idea of this feeling, becomes in time so closely associated with all our sensations of touch and sight, that the one cannot be separated from the other, and these associations are what Dr Priestley calls extended ideas. Upon the whole, then, we think it apparent that our sensations, and the relicts of our sensations, are unextended and indivisible; and that though they suggest to us the existence of extended things *ab extra*, the sentient being may be unextended and indivisible.

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The sentient principle cannot be material.

Having thus examined Dr Priestley's auxiliary arguments for the materiality of mind, we now proceed to consider his main and direct proof. To this, as we have observed, so able a reply has been made, that it would be injustice to our readers not to lay it before them, in the words of its author. "I readily acknowledge," says this acute and spirited essayist,[1] "that the power of sensation or perception never having been found but in conjunction with a certain organized system of matter, we ought, as philosophers, to conclude that this power necessarily exists in, and results from, that organized system, unless it can be shown to be incompatible with other known properties of the same substance. On the other hand, it must be admitted, that constant conjunction implies necessary connections only when reasons cannot be discovered to prove the conjunction to be accidental and arbitrary. In the present instance it is alleged, that discerptibility is a property of matter absolutely incompatible with the property of sensation or perception; or, in other words, that sensation is a power or property incapable of division. But as the power of the entire system is clearly nothing more than the sum or aggregate of the powers of all the parts, it necessarily follows, that the primary particles of which the system is composed must, upon the material hypothesis, pos-

[1] Essays, Philosophical, Historical, and Literary, vol. ii.

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sess distinct powers of sensation, and that those powers combined constitute the indivisible power of sensation belonging to the system; or, in other words, that the indivisible power of sensation is a divisible power, nay, an infinitely divisible power, if matter be, as philosophers in general allow, an infinitely divisible substance, a conclusion obviously and grossly ridiculous. We are then compelled to acknowledge that sensation or perception is not the property of a material substance; that is, if the common mode of expression be retained, it is the property of an immaterial substance; or, to avoid verbal contention, it is a property not resulting from, or necessarily connected with, the organical system, but a property wholly foreign, superinduced, and adventitious.

"In opposition to this reasoning, the materialists affirm, that entire systems may possess, and they think themselves warranted to pronounce that organized systems of matter actually do possess, powers essentially different from those which inhere in the several parts. Amongst various familiar though striking illustrations of this truth, it has been said, that a rose possesses the property of sweetness or fragrance, a globe the property of sphericity, a harpsichord the property or power of producing harmony, *aqua regia* the property of dissolving gold, &c. though the component particles of these different organized systems are themselves totally destitute of the powers and properties here enumerated.

"The immaterialists, in reply, assert that it is not only false in fact, but a direct contradiction, and an absolute impossibility in the nature of things, that a system should possess any property which does not inhere in its component parts. To assert that the power of the whole is the sum or aggregate of the powers of all the parts, is an identical and self-evident proposition, the whole and all the parts being terms precisely synonymous. Whoever, therefore, calls in question the truth of this axiom, must maintain that the power of the whole is something different from the power of all the parts, or that the power of the whole is *not* the power of the whole.

"It will be easy to demonstrate the correspondence of facts with this plain and simple theory. For this purpose, it is necessary to observe, that the properties of matter, or what are generally denominated such, may be divided into real and nominal, which Locke and others have called primary and secondary qualities. Figure, magnitude, and motion, are qualities really inherent in matter; but figure, magnitude, and motion, eternally varied, can produce only different combinations of figure, magnitude, and motion. There are also powers or qualities, vulgarly considered as inherent properties of matter organically disposed, which are really and truly qualities or affections of the mental or percipient principle, and have no existence when not perceived. Thus the sweetness or fragrance of the rose, considered as mere sweetness and fragrance, can be nothing but an affection of the mind; considered as a quality of the rose, they can mean nothing more than a certain arrangement, configuration, and motion of parts, which in some inexplicable manner produces the sensation of sweetness. In this instance, therefore, the power of the whole is plainly the aggregate of the powers residing in the parts, by the motion and organization of which a certain effect is produced upon a foreign and percipient substance.

"But a globe, we are told, possesses the property of sphericity, though not a single particle amongst that infinite number of which the globe is constituted is itself of a spherical form. The fallacy of this illustration is, however, as easily demonstrable as that of the former. The sphericity of a globe is evidently the sum or aggregate of the curvilineal or convex parts which compose its surface; and the property of the whole is neither more nor less than the combined properties of all its parts. No one doubts, that by new compositions or arrangements of material particles possessing magnitude, figure, and motion, an endless diversity of phenomena may be produced, to which it may be necessary to apply new names. New names, however, do not constitute new properties; and though we give to a globe the appellation of an entire system, and ascribe to it the property of sphericity, we know at the same time that it is really nothing more than a collection of thousands of millions of particles, actually separate and distinct, arranged in that particular form which we denominate spherical. But this can never be regarded as in the remotest manner analogous to the creation of the power of perception, in consequence of a certain organical arrangement or disposition of impercipient particles. Though sphericity is, indeed, the property of the entire sphere, yet every part of the sphere, if divided, possesses its share of sphericity. But if the percipient principle be divided, what would become of the power of perception? A sphere equally divided becomes two hemispheres; does a perception, when divided in like manner, become two demi-perceptions?

"The same reasonings may easily be transferred, and applied to the harpsichord. Can any one be absurd enough to affirm that the power of harmony resides in the harpsichord, as the power of perception does in the mind? After the utmost skill of the artificer has been exerted, we discover nothing more in the harpsichord than new modifications of the old properties of figure, magnitude, and motion, by means of which certain vibrations are communicated to the air, which, conveyed by the medium of the auditory nerves to the sensorium, produce the sensation of harmonic sounds. These new modifications are therefore attended, indeed, with new and very wonderful effects; but then those effects are produced upon, and are themselves modifications of, the sentient or percipient faculty. And though it is wholly incomprehensible to us in what manner these effects, that is, these sensations, are produced, we well know, and perfectly comprehend, that they are not new powers belonging to any organized system of matter; that they have no existence but in a mind perceiving them; and that they are far from militating against that grand and universal axiom, that the power of the whole is nothing more than the united powers of all the parts.

"As to the last instance adduced, of the power of *aqua regia* to dissolve gold, though neither the spirit of salt, nor the spirit of nitre of which it is compounded, separately possesses that power, it is plain, that from the union of these two substances, certain new modes of configuration and motion result; and the solution of gold is the consequence of this new arrangement and motion of the parts. But the particles of which the menstruum is composed were always possessed of the properties of figure and motion; and what is styled a new property is clearly nothing more than a new effect of the old properties differently modified. In a word, the advocates for materialism may safely be challenged to produce, in the whole compass of nature, a case which bears the least analogy to that which these instances are most unphilosophically adduced to prove and to illustrate. It is an absurdity which transubstantiation itself does not exceed, to maintain that a whole is in reality any thing different from its component parts; and all nature rises up in confutation of an assertion so monstrous and extravagant. To affirm that perception can arise from any combination of impercipient particles, is as truly ridiculous as to affirm that a combination of the seven primary colours with the four cardinal virtues may constitute a planet. It is equivalent to an assertion, that an epic poem might be composed of parallelograms, cones, and triangles. In a word, it is an absurdity not less real, and a little less obvious, than that of the blind man who thought that the idea of a scarlet colour resembled the sound of a trumpet."

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If matter be taken in the common acceptation to be a solid, extended, and inert substance, this reasoning for the immateriality of the sentient principle in man appears to us to have the force of demonstration, which no difficulties or partial objections, arising from our inability to conceive the band of union between two such heterogeneous substances as mind and body, can ever weaken, and far less overturn.

Reply by the materialists.

But the modern materialists deny that matter is either solid or inert. "All those facts," say they, "which led philosophers to suppose that matter is impenetrable to other matter, later and more accurate observations have shown to be owing to something else than solidity and impenetrability, viz. a power of repulsion, which for that reason they would substitute in its place. The property of attraction or repulsion, says Dr Priestley, appears to me not to be properly what is imparted to matter, but what really makes it to be what it is; insomuch that, without it, it would be nothing at all; and as other philosophers have said, 'Take away solidity, and matter vanishes,' so I say, 'Take away attraction and repulsion, and matter vanishes.'" If this be admitted, the ingenious author hopes that we shall not consider matter with that contempt and disgust with which it has generally been treated, there being nothing in its real nature that can justify such sentiments respecting it.

Rejoinder.

We know not why, upon any hypothesis, matter should be viewed with contempt and disgust. Whether penetrable or impenetrable, every consistent theist considers it as one of the creatures of God, perfectly fitted to answer all the purposes for which it was intended; but were it really destitute of solidity, and endowed with the powers of attraction and repulsion, we should still be obliged to consider it as incapable of the powers of sensation and thought. If we have any notion at all of what is meant by centres of attraction and repulsion (of which indeed we are far from being confident), it appears to us to be intuitively certain, that nothing can be the result of any possible combination of such centres, but new and more enlarged spheres of attraction and repulsion. But surely consciousness, sensation, and will, are as different from attraction and repulsion, as a cube is from the sound of a trumpet, or as the sensations of a felon in the agonies of death are from the attraction of the rope by which he is hanged. If this be admitted, and we are persuaded that it will not be denied by any man whose understanding is not clouded by an undue attachment to paradoxes, the sentient principle cannot possibly be matter; for if, when the powers of attraction and repulsion are taken away, matter vanishes, and if consciousness and sensation are not attraction and repulsion, it is not more evident that three and two are not nine, than that the substance which attracts and repels cannot be that which is conscious and percipient.

Locke's opinion.

Locke, who was certainly no materialist, as he repeatedly affirmed, and indeed demonstrated, that thought could never be the result of any combinations of figure, magnitude, and motion, was nevertheless of opinion that God by his almighty power might endow some systems of matter with the faculties of thinking and willing. It is always with reluctance that we controvert the opinions of so great a man; and it is with some degree of horror that we venture in any case to call in question the power of Omnipotence. But Omnipotence itself cannot work contradictions; and it appears to us nothing short of a contradiction to suppose the individual power of perception inhering in a system which is itself extended and made up of a number of separate and distinct substances. For let us suppose such a system to be six feet long, three feet broad, and two feet deep (and we may as well suppose a system of these dimensions to be percipient as one that is smaller), then it is plain that every idea must be extended, and that part of it must be in one place and part in another. If so, the idea of a square inch will be six feet long, three feet broad, and two feet deep; and, what is still harder to be digested, the several parts of this idea will be at a great distance from each other, without any bond of union amongst them. The being which apprehends one extremity of the idea is, by the supposition, six feet distant from the being which apprehends the other extremity; and although these two distinct beings belong to one system, they are not only separable, but actually separated from each other, as all the particles of matter are. What is it, then, that apprehends as one the whole of this extended idea? Part of it may be apprehended by one particle of matter, and part of it by another; and there is nothing which apprehends or can apprehend the whole. Perhaps it will be said, that the power of apprehension is not divided into parts, but is the power of the one system, and therefore apprehends at once the whole idea. But a power or faculty cannot be separated from its subject, power which inheres in nothing being confessedly impossible; and a material system is not one subject in which any individual power or faculty can inhere. There must, therefore, be united to the system some one being, which is the subject of thought, and which is unextended as well as indivisible. This, we say, follows undeniably. For let us suppose that an extended being without separate parts is possible, and that such a being is percipient; it is obvious that the whole of any one of its perceptions could not be in one place. Now, although we should grant to Dr Priestley and other materialists that every idea of an extended substance has itself three dimensions, and is incorporated and commensurate with the whole percipient system; what, upon this supposition, shall we think of consciousness and of the perception of truth? Is consciousness or truth extended? If so, one side or superficies of consciousness, or of a truth, may be greater or less than another, above or below, to the right or to the left; and it will be very proper and philosophical to speak of the length, breadth, and depth, of consciousness or of truth. But surely to talk of the place or the extension of these things, is as absurd as to talk of the colour of sound, or the sound of a triangle; and we might as well say that consciousness is green or red, as that it is an ell or an inch long; and that truth is blue, as that it has three dimensions.

Cudworth's statement of this reasoning.

This reasoning is somewhat differently stated by Cudworth, who observes, that if the soul be an extended substance, "it must of necessity be either a physical point (that is, the least extension possible, if there be any such least extension), or else it must consist of more such physical points joined together. As to the former of these, it is impossible that one single atom, or smallest point of extension, should be able to perceive distinctly all the variety of things, that is, take notice of all the distinct and different parts of an extended object, and have a description or delineation of the whole of them upon itself (for that would be to make it the least, and not the least, possible extension at the same time). Besides, to suppose every soul to be but one physical point, or the smallest possible extension, is to suppose such an essential difference in matter or extension, as that some of the points thereof should be naturally devoid of all life, sense, and understanding; and others, again, naturally sensitive and rational. And even should this absurdity be admitted, it would yet be utterly inconceivable how there should be one, and but one, sensitive and rational atom in every man; how this atom of so small dimensions should actuate the whole system, and how it should constantly remain the same from infancy to old age, whilst all the other parts of the system transpire perpetually, and are succeeded by new matter.

"But if, according to the second hypothesis, souls be extended substances, consisting of many points one without another, and all concurring in every sensation, then must every one of these points perceive either a point only of the object, or else the whole. Now, if every point of the ex-

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tended soul perceives only a point of the object, then there is no one thing in us that perceives the whole, or that can compare one part of the object with another. On the other hand, if every point of the extended soul perceive the whole object at once, then would there be innumerable perceptions of the same object in every sensation, as many, indeed, as there are points in the extended soul. And from both these suppositions it would alike follow that no man is one single percipient or person, but that in every man there are innumerable distinct percipients or persons; a conclusion directly contrary to the infallible evidence of consciousness."

Cogent as these arguments for the immateriality of the sentient principle appear to be, they have nevertheless been treated with the most sovereign contempt by a writer who professes to be a disciple of Dr Priestley's, but who seems not to have learned the modesty or the candour of his master. Dr Priestley labours to prove, that to account for the phenomena of perception and volition, &c. it is not necessary to suppose an immaterial principle in man. Mr Cooper with greater boldness affirms, and undertakes to demonstrate, with all the parade of mathematical precision, that such a principle is impossible.[1] Though the authority of this philosopher in such inquiries as depend not immediately upon the retort and the furnace, is certainly not great, he yet utters his dogmas with such confidence, that it may not be improper to examine the chief arguments upon which they rest.

Futile attempt to prove the impossibility of immaterial substance.

"Suppose," says he, "the soul to have no common property with matter, then no thing can act upon any other but by means of some common property. Of this we have not only all the proof that induction of known and acknowledged cases can furnish, but that additional proof also which arises from the impossibility of conceiving how the opposite proposition can be true. But by the supposition the soul has no property in common with matter, and therefore the soul cannot act upon matter. But by the supposition of every system of immaterialism (except those of Malebranche, Berkeley, and Leibnitz), it is deemed an essential property of the soul that it acts upon the body, or upon matter; therefore the soul can and cannot act upon matter at the same time, and in the same respect. But this is a contradiction in terms; and as two contradictions cannot both be true at the same time, the supposition of the existence of an immaterial soul cannot be true; that is, the soul does not exist."

This reasoning, as the reader will observe, is carried on with all the pomp of mode and figure. The propositions hang upon each other like the several steps of an algebraical process; but as in such processes one error unwarily admitted produces a false result, so in demonstrative reasonings one unsound argument admitted into the premises is necessarily productive of error in the conclusion. When the author affirms, "that no thing can act upon any other but by means of some common property," he affirms, without the shadow of proof, what is certainly not self-evident. He says, indeed, that of this we have all the proof that induction of known and acknowledged cases can furnish; but unless consciousness be calculated to deceive us, this is unquestionably a mistake. Matter, he repeatedly affirms, has no other properties than those of attraction and repulsion; but a man moves his arm by a mere energy of will, and, therefore, according to this demonstrator, an energy of will must be either material attraction or material repulsion. If so, it is reasonable to conclude that when a man draws his hand towards his head, the centre of his brain exerts its power of attraction; and that when he extends his arm at full length before him, the same centre exerts its power of repulsion. We beg pardon of our readers for detaining them one moment upon such absurdities as these; yet we cannot dismiss the argument without taking the liberty to ask our all-knowing author, how it comes to pass that the same centre sometimes attracts and sometimes repels the same substance at the same distance; nay, that it both attracts and repels substances of the same kind, at equal distances, and at the very same instant of time? This must be the case when a man puts one hand to his head and thrusts another from him; and, therefore, if these operations be the effect of attraction and repulsion, it must be of attraction and repulsion to which induction of known and acknowledged cases furnishes nothing similar or analogous, that is, of such attraction and repulsion as, according to Mr Cooper's mode of reasoning, does not exist. The truth is, that we are not more certain that we ourselves exist, than that an energy of will is neither attraction nor repulsion; and, therefore, unless all matter be endued with will, it is undeniable that, whatever be the substance of the soul, one thing acts upon another by a property not common to them both. In what manner it thus acts, we pretend not to know; but our ignorance of the manner of any operation is no argument against the reality of the operation itself, when we have for it the evidence of consciousness and daily experience; and when the author shall have explained to general satisfaction how material centres attract and repel each other at a distance, we shall undertake to explain how one thing acts upon another with which it has no common properties.

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Suspicious, as it should seem, that this reasoning has not the complete force of mathematical demonstration, the author supports his opinion by other arguments. "Whatever we know," says he, "we know by means of its properties, nor do we in any case whatever certainly know any thing but these; and we infer in all cases the existence of any thing which we suppose to exist from the existence of its properties. In short, our idea of any thing is made up of a combination of our ideas of its properties. Gold is heavy, ductile, tenacious, opaque, yellow, soluble in *aqua regia*, &c. Now, let any one suppose for an instant that gold is deprived of all these, and becomes neither heavy, nor ductile, tenacious, opaque, yellow, soluble, &c.; what remains? will it be gold? Certainly not. If it have other properties, it is another substance. If it have no properties remaining, it is nothing. For nothing is that which hath no properties. Therefore, if any thing lose all its properties, it becomes nothing; that is, it loses its existence. Now the existence of the soul is inferred, like the existence of every thing else, from its supposed properties, which are the phenomena of thinking, such as perception, recollection, judgment, and volition. But in all cases of perfect sleep, of the operation of a strong narcotic, of apoplexy, of swooning, of drowning where the vital powers are not extinguished, of the effects of a violent blow on the back part of the head, and all other leipothymic affections, there is neither perception, recollection, judgment, nor volition; that is, all the properties of the soul are gone, are extinguished. Therefore, the soul itself loses its existence for the time. If any man shall say, that these properties are only suspended for the time, I would desire him to examine what idea he annexes to this suspension; whether it be not neither more nor less than that they are made not to exist for the time. Either no more is meant, or it is contradictory to matter of fact; and, moreover, if more be meant, it may easily be perceived to involve the archetypal existence of abstract ideas, and to contradict the axiom *impossibile est idem esse et non esse*."

[1] Tracts Ethical, Theological, and Political, vol. i.

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For the benefit of short-sighted inquirers, it is to be wished that the author had favoured the public with this proof, which might have been so easily brought forward; for we can discern no connection whatever between the suspension of the exercise of the powers of the mind, and the archetypal existence of abstract ideas, or the absurd proposition that it is possible for the same thing to be and not to be. We think, however, that we understand enough of this reasoning which he has given us, to be able to pronounce with some confidence that it is nothing to the purpose. For, in the first place, we beg leave to observe, that between the properties of gold and the powers of thinking, &c. there is no similarity; and that what may be true when affirmed of the one, may be false when affirmed of the other. The powers of the mind are all more or less active; but the enumerated properties of gold are all passive. We know by the most complete of all evidence, that the exercise of power may be suspended, and yet the power itself remain unimpaired; but to talk of the suspension of the energies of what was never energetic, if it be not to contradict the axiom, *impossibile est idem esse et non esse*, is certainly to employ words which have no meaning. Yet even this argument from the properties of gold might have led the author to suspect that something else may be meant by the suspension of the exercise of powers, than that those powers are made not to exist for the time. In a room perfectly dark, gold is not yellow; but does it lose any of its essential properties, and become a different substance, merely by being carried from light to darkness? Is a man, whilst in a dark room, deprived of the faculty of sight, and is one of the powers of his mind made not to exist for the time? The author will not affirm that either of these events takes place. He will tell us that gold exhibits not its yellow appearance merely because the proper medium of light passes not from it to the eye of the percipient, and that it is only for want of the same medium that nothing is seen by us in perfect darkness. Here, then, by his own confession, is a power of the mind, and a property of an external object, both suspended in their energies, without being annihilated; and no proof has yet been brought that all the powers of the mind may not in the same manner be suspended in their energies without being made not to exist. As light is necessary to vision, but is not itself either the thing which sees or the thing which is seen, so may the brain be necessary to the phenomena of thinking, without being either that which thinks, or that which is thought upon; and as actual vision ceases when light is withdrawn, although the eye and the object both continue to exist, so may the energy of thinking cease when the brain is rendered unfit for its usual office, although the being which thinks, and the power of thought, continue to exist, and to exist unimpaired. That this is actually the case, every man must be convinced who believes that in thinking he exerts the same powers to-day which he exerted yesterday; and therefore our author's second demonstration of the non-existence of mind is, like his first, founded upon assertions which cannot be granted.

A third attempt of the same kind confuted.

Another of these pretended demonstrations is as follows: "If the soul exist at all, it must exist somewhere; for it is impossible to frame to one's self an idea of any thing existing, which exists nowhere. But if the soul exist somewhere, by the terms it occupies space, and therefore is extended; but whatever has extension, has figure in consequence thereof. The soul, then, if it exist, hath the properties of extension and figure in common with matter. Moreover, by the supposition of every immaterial hypothesis (except those of Malebranche, Berkeley, and Leibnitz), it acts upon body, or upon matter; that is, it attracts and repels, and is attracted and repelled, for there is no conceivable affection of matter but what is founded on its properties of attraction and repulsion; and if it be attracted and repelled, its re-action must be attraction and repulsion. The soul, then, has the properties of extension, figure, attraction, and repulsion, or solidity. But these comprise every property which matter, as such, has ever been supposed to possess. Therefore the soul is matter, or material. But by the supposition it is immaterial; therefore it does not exist. For nothing can exist whose existence implies a contradiction."

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Mr Cooper, we see, still proceeds in the direct road of mathematical demonstration; but in the present instance we beg leave to stop him in the very beginning of his course, and to ask him *where* the universe exists? When he shall have given such an answer to this question as men of common sense may be able to comprehend, we may perhaps attempt to tell him where an unextended soul exists. If this demonstration be not a collection of words without meaning, the existence of space as a real thing is taken for granted. Space, therefore, has extension, and of course figure; but we believe Mr Cooper will find some difficulty in ascertaining the figure of infinite space. The mind certainly acts upon body. For this we have the evidence of consciousness and experience; but we have no evidence whatever that it must therefore attract and repel, and be attracted and repelled. It has been already observed, that the mind, whatever be its substance, acts upon the body by energies of will. What these are, every man knows with the utmost certainty and precision; whilst we may venture to assert, that no man knows precisely what corpuscular attraction and repulsion are, even supnposig the existence of such powers to be possible. When we speak of attraction and repulsion, we have some obscure notion of bodies acting upon each other at a distance; and this is all that we know of the matter. But when we think of an energy of the human will, the idea of distance neither enters nor can enter into our notion of such an energy. These are facts which we pretend not to prove by a mathematical or a chemical process. Every man must be convinced of their truth by evidence more complete than any proof, viz. immediate consciousness of his own thoughts and volitions. This being the case, we may turn Mr Cooper's artillery against himself, and, because mind acts upon body by powers different from attraction and repulsion, argue that body neither attracts nor repels; and were it true, as it is certainly false, that one thing could not act upon another but by means of some property common to both, we might infer that every atom of matter is endowed with the powers of volition and, intelligence, and, by consequence, that every man is not one but ten thousand conscious beings; a conclusion which our philosopher seems not inclined to admit.

Objections to the doctrine of immaterialism answered.

Having finished his *demonstrations*, the author states other objections to the doctrine of immaterialism, which, as they are not his own, nor new, have greater weight. "It appears no more than reasonable," says he, "that if the doctrine of materialism be rejected as inadequate to explain the phenomena, these latter should at least be explained in some manner or other better upon the *substituted* than *rejected* hypothesis; so that it is reasonable to require of an immaterialist that his supposition of a distinct soul should explain the *rationale* of the phenomena of thinking. But, strange to say, so far from attempting to explain these phenomena on the immaterial hypothesis, it is acknowledged on all hands, that, even on this hypothesis, the phenomena are inexplicable." This objection it would certainly be no difficult task to obviate; but from that trouble, small as it is, we are happily exempted by the objector himself. "I would have it understood," says he, "that no materialist ever undertook to say how perception results from our organization. What a materialist undertakes to assert is, that perception, whatever it be, or however it results from, does actually result from our organization." According to Mr

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Cooper, then, the *rationale* of thinking is equally inexplicable by materialists and immaterialists; and the truth is, that we know the *rationale* of hardly any one operation in nature. We see that the stroke of a racket produces motion in a billiard ball; but how it does so, we believe no man can say. Of the fact, however, we are certain; and we know that the motion is produced by some power, about the effects of which we can reason with precision. In like manner we know with the utmost certainty, that we ourselves possess the powers of perception and volition; and that these powers cannot be conceived as either an ell or an inch in length. How they result from the mutual agency of an immaterial and material substance upon each other, we are indeed profoundly ignorant; but that such is the fact, and that they are not the result of mere organization, we must necessarily believe, so long as it is true that the power of the entire system is nothing more than the sum or aggregate of the powers of all its parts. The immaterial hypothesis contains in it something inexplicable by man. The material hypothesis likewise contains, by the confession of its advocates, something that is equally inexplicable; and is, besides, burdened with this glaring contradiction, that the whole is something different from all its parts. It is therefore no "singular phenomenon in literary history, that one hypothesis should be rejected as inadequate to account for appearances, and that the hypothesis substituted should, even by the acknowledgment of its abettors, be such as not only not to explain the *rationale* of the appearances, but, from the nature of it, to preclude all hopes of such an explanation." This is exactly the case with respect to a *vacuum* in astronomy. That hypothesis does not in the least tend to explain the *rationale* of the motions of the planets; but yet it must be admitted in preference to a *plenum*, because upon this last hypothesis motion is impossible.

Whether as much may be affirmed of the soul as of the body.

"Supposing the existence of the soul, it is an unfortunate circumstance," says Mr Cooper, "that we cannot properly assert positively any thing of it at all. Were this the case, it would indeed be a very unfortunate circumstance; but can we not assert positively as many things of the soul as we can of the body? Can we not say with as much propriety and certainty, that the soul has the powers of perception and volition, &c. as that the body is solid and extended, or as that matter has the powers of attraction and repulsion?" We know perfectly what perception and volition are, though we cannot have ideas or mental images of them; and if our author knows what attraction and repulsion are, we believe he will not pretend to have ideas of them entirely abstracted from their objects. "But granting the soul's existence, it may be asked," says he, "of what use is an hypothesis of which no more can be asserted than its existence?" We have just observed that much more can be asserted of the soul than its existence, viz. that it is something of which perception and will are properties; and he himself asserts nothing of matter, but that it is something of which attraction and repulsion are properties.

"This soul, of which these gentlemen (the immaterialists) are conscious, is immaterial essentially. Now I deny," says our author, "that we can have any idea at all of a substance purely immaterial." He elsewhere says, that nothing can exist which is not extended, or that extension is inseparable from our notions of existence. Taking the word *idea* in its proper sense, to denote that appearance which external objects make in the imagination, it is certainly true that we can have no idea of an immaterial substance; but neither have we, in that sense, any idea of matter abstracted from its qualities. Has Mr Cooper any idea of that which attracts and repels, or of attraction and repulsion, abstracted from their objects? He may perhaps have, although we have not very adequate ideas of bodies acting upon each other at a distance; but as he takes the liberty to substitute assertions for arguments, we beg leave in our turn to assert, that those ideas neither are, nor can be, more clear and adequate than our notion of perception, consciousness, and will, united in one being.

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Extension not inseparable from all notions of existence.

That extension is no otherwise inseparable from our notions of existence than by the power of an early and perpetual association, is evident from this circumstance, that, had we never possessed the senses of sight and touch, we never could have acquired any idea at all of extension. No man who has thought on the subject will venture to affirm, that it is absolutely impossible for an intelligent being to exist with no other senses than those of smell, taste, and hearing. Now it is obvious that such a being must acquire some notion of existence from his own consciousness. But into that notion extension could not possibly enter; for neither sounds, tastes, smells, nor consciousness, are extended; and it is a fundamental article of the materialist's creed, that all our ideas are relicts of sensation. Since, then, existence may be conceived without extension, it may be inferred that they are not inseparable from each other; and since cogitation cannot be conceived with extension, we may reasonably conclude, that the being which thinks is not extended.

Mr Cooper, indeed, with his master, talks of extended ideas and extended thoughts. But we must assert, in the words of Cudworth, that "we cannot conceive a thought to be of such a certain length, breadth, and thickness, measurable by inches, feet, and yards; that we cannot conceive the half, or third, or twentieth part of a thought; and that we cannot conceive every thought to be of some determinate figure, such as round or angular, spherical, cubical, cylindrical, or the like. Whereas if extension were inseparable from existence, thoughts must either be mere nonentities, or extended into length, breadth, and thickness; and consequently all truths in us being nothing but complex thoughts, must be long, broad, and thick, and of some determinate figure. The same must likewise be affirmed of volitions, appetites, and passions, and of all other things belonging to cogitative beings, such as knowledge and ignorance, wisdom and folly, virtue and vice, that these are either all of them absolute nonentities, or else extended into three dimensions, and measurable not only by inches and feet, but also by solid measures, such as pints and quarts. But if this be absurd, and if these things belonging to soul and mind, though doubtless as great realities at least as the things which belong to body, be unextended, then must the substances of souls or minds be themselves unextended, according to that of Plotinus, νους οὐ διαστας ἀφ' ἑαυτου, and therefore the human soul cannot be material."

Alleged materiality of the sentient principle.

Mr Cooper employs many other arguments to prove the materiality of the sentient principle in man; but the force of them extends no farther than to make it in the highest degree probable, that the mind cannot exert its faculties except in union with some organized corporeal system. This is an opinion which we do not feel ourselves inclined to controvert; and therefore we shall not make any particular remarks upon that part of our author's reasonings. That an immaterial and indiscerptible being, such as the soul, is not liable to be dissolved with the body, is a fact which cannot be controverted; for that which has no parts can perish only by annihilation; and of annihilation the annals of the world afford no instance. That an immaterial being, endowed with the powers of perception and volition, &c. may be capable of exerting these powers in a state of separation from all body, and that at least one immaterial Being does actually so exert them, or other powers analogous to them, are truths which no man whose arrogance does not surpass his judgment will venture to deny; but the question at present between the most rigid immaterialists and their

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opponents is, whether there be ground to think that the human soul is such a being?

Opinion of Baxter and others.

Now, when Mr Baxter and his followers confidently affirm, that human perception must necessarily subsist after the dissolution of the present mortal and perishable system, and that the soul, when disencumbered of all body, will have its faculties greatly enlarged, they affirm what to us appears incapable of proof. That a disembodied soul may perceive, and think, and act, and that its powers of intellection may have a wider range than when they were circumscribed by a corporeal system, which permitted their action upon external objects only through five organs of sense, is certainly possible; and the argument by which the materialists pretend to prove that it is not possible, is one of the most contemptible sophisms that ever disgraced the history of philosophy. To affirm, that because our intellectual powers, in their embodied state, seem to decay with the system to which they are united, the mind, when set free, must therefore have no powers at all, is equally absurd as to say, that because a man shut up in a room which has but one window sees objects less and less distinctly as the glass becomes more and more dimmed, he must in the open air be deprived of the power of vision. But because the human soul may, for any thing that we see to the contrary, subsist, and think, and act, in a separate state, it does not therefore necessarily follow that it will do so; and every thing that we know of its nature and its energies leads us to think, that without some kind of body by which to act as by an instrument, all its powers would continue dormant. There is not the shadow of a reason to suppose that it existed and was conscious in a prior state; and as its memory at present unquestionably depends upon the state of the brain, there is all the evidence of which the case will admit, that if it should subsist in a future state divested of all body, though it might be endowed with new and enlarged powers of perception, it could have no recollection of what it did and suffered in this world, and therefore would not be a fit object either of reward or of punishment.

Notion that at death the soul carries with it a fine material vehicle.

This consideration has compelled may thinking men, both Pagans and Christians, to suppose that at death the soul carries with it a fine material vehicle, which is its immediate sensorium in this world, and continues to be the seat of its recollection in the next. Such, as we have seen, was the opinion of Mr Wollaston and Dr Hartley; it was likewise the opinion of Cudworth and Locke, who held that the Supreme Being alone is the only mind wholly separated from matter; and it is an opinion which even Dr Clarke, one of the ablest advocates for immaterialism, would not venture positively to deny. Nor is this opinion peculiar to a few moderns. Cudworth, after giving a vast number of quotations from Pythagoreans and Platonists, which prove to a demonstration that they held the Deity to be the only mind which perceives and acts without the instrumentality of matter, observes, "From what hath been said, it appeareth that the most ancient assertors of the incorporeity and immortality of the human soul yet supposed it to be always conjoined with some body." Thus Hierocles plainly: "The rational nature having always a kindred body, so proceeded from the demiurgus, that neither itself is body, nor yet can it be without body; but although itself be incorporeal, yet its whole form is terminated in a body." Agreeably to this, the definition which he gives of a man is, "a rational soul, together with a kindred immortal body;" and he affirms, that our present animated terrestrial body, or mortal man, is nothing but εἴδωλον ἀνθρωπου, "the image of the true man," or an accession from which it may be separated. Neither does he affirm this only of human souls, but also of all other rational beings whatsoever below the Supreme Deity, that they always naturally actuate some body. Wherefore a demon or angel, which by Hierocles are used as synonymous words, is also defined by him, after the same manner, to be "a rational soul, together with a lucid body." And accordingly, Proclus upon Plato's Timæus affirms, "That every demon, superior to human souls, hath both an intellectual soul and an ethereal vehicle, the entireness thereof being made up or compounded of these two things." So that there is hardly any other difference between demons or angels and men, according to these philosophers, but only this, that the former are lapsable into aërial bodies only, and no further; but the latter into terrestrial also. Now, Hierocles positively affirms this to have been the true cabbala and genuine doctrine of the ancient Pythagoreans, entertained afterwards by Plato: "And this was the doctrine of the Pythagoreans, which Plato afterwards declared; he resembling every soul both human and divine (that is, in our modern language, every created rational being) to a winged chariot and a driver or charioteer both together;" meaning by the chariot an animated body, and by the charioteer the incorporeal soul actuating it.

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The Pythagorean notion of the Deity adopted by the early Christians.

That this Pythagorean opinion of the Deity's being the only mind which thinks and acts without material organs was very generally received by the ancient Christians, might be proved by a thousand quotations. We shall content ourselves with producing two from the learned Origen: "Solius Dei," says this philosophic father of the church, "id est, Patris, Filii, et Spiritus Sancti, naturæ id proprium est, ut sine materiali substantia, et absque ulla corporeæ adjectionis societate, intelligatur subsistere." "Materialem substantiam opinione quidem et intellectu solum separari, a naturis rationalibus, et pro ipsis, vel post ipsas affectam videri; sed nunquam sine ipsa eas vel vixisse, vel vivere: solius namque Trinitatis incorporea vita existere putabitur." Should Mr Cooper and his friends ask, What is the use of a *soul* which cannot act without the instrumentality of matter? or why we should suppose the existence of such a substance? we beg leave, in our turn, to inquire of these gentlemen, What is the use of a brain which cannot see *without eyes*? and why they should suppose all our sensations to terminate in such an internal system, since the vulgar certainly suppose their sensations to subsist in their respective organs? How this ancient notion, which makes body so essential a part of man, is consistent with the immortality of the human soul, we shall inquire in a subsequent chapter; in which we shall endeavour to ascertain what kind of immortality we have reason to expect, and upon what evidence our expectation must rest. Previously to this inquiry, however, it is necessary to enter upon another, which is of the first importance, and which every materialist has endeavoured to perplex; we mean that which concerns personal identity; for if, as has been often said, no man is the same person two days successively, it is of but little importance to us whether the soul be mortal or immortal.

CHAP. III.—OF PERSONAL IDENTITY.

Personal identity.

Whether we are to exist in a future state, as it is the most important question which can possibly be asked, so it is the most intelligible one which can be expressed in language. Yet strange perplexities have been raised about the meaning of that identity or sameness of person which is implied in the notion of our living now and hereafter, or indeed in any two successive moments; and the solution of these difficulties has been stranger than even the difficulties themselves. To repeat all that has been said on the subject would swell this chapter to a disproportionate bulk. We shall therefore content ourselves with laying before our readers the sentiments of Bishop Butler, and the fan-

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cies and demonstrations of the philosopher of Manchester. We are induced to adopt this course, because we think that the illustrious Bishop of Durham has exhausted the subject, by stating fairly the opinions which he controverts, and by establishing his own upon a foundation which cannot be shaken, and which are certainly not injured by the objections of Mr Cooper.

Easily understood and ascertained by consciousness and memory.

"When it is asked," says this philosophical prelate,[1] "in what personal identity consists? the answer should be the same as if it were asked in what consists similitude or equality? that all attempts to define would but perplex it. Yet there is no difficulty at all in ascertaining the idea or notion: For as, upon two triangles being compared or viewed together, there arises to the mind the notion of similitude, or upon twice two and four the notion of equality; so likewise, upon comparing the consciousness of one's self or one's own existence in any two moments, there as immediately arises to the mind the notion of personal identity. And as the two former comparisons not only give us the notions of similitude and equality, but also show us that two triangles are similar, and that twice two and four are equal; so the latter comparison not only gives us the notion of personal identity, but also shows us the identity of ourselves in these two moments, the present, suppose, and that immediately past, or the present and that a month, a year, or twenty years past. In other words, by reflecting upon that which is myself now, and that which was myself twenty years ago, I discern they are not two, but one and the same self.

But these do not make personal identity.

"But though consciousness of what is present and remembrance of what is past do thus ascertain our personal identity to ourselves, yet, to say that remembrance makes personal identity, or is necessary to our being the same persons, is to say that a person has not existed a single moment, nor done one action, but what he can remember, indeed none but what he reflects upon. And one should really think it self-evident, that consciousness of personal identity presupposes, and therefore cannot constitute, personal identity, any more than knowledge, in any other case, can constitute truth, which it presupposes.

"The inquiry, what makes vegetables the same in the common acceptation of the word, does not appear to have any relation to this of personal identity; because the word *same*, when applied to them and to person, is not only applied to different subjects, but is also used in different senses. When a man swears to the same tree, as having stood fifty years in the same place, he means only the same as to all the purposes of property and uses of common life, and not that the tree has been all that time the same in the strict philosophical sense of the word; for he does not know whether any one particle of the present tree be the same with any one particle of the tree which stood in the same place fifty years ago. And if they have not one common particle of matter, they cannot be the same tree in the proper and philosophic sense of the word *same;* it being evidently a contradiction in terms to say they are, when no part of their substance and no one of their properties is the same; no part of their substance, by the supposition; no one of their properties, because it is allowed that the same property cannot be transferred from one substance to another; and, therefore, when we say that the identity or sameness of a plant consists in a continuation of the same life, communicated under the same organization to a number of particles of matter, whether the same or not, the word *same*, when applied to life and to organization, cannot possibly be understood to signify what it signifies in this very sentence, when applied to matter. In a loose and popular sense, then, the life, and the organization, and the plant, are justly said to be the same, notwithstanding the perpetual change of the parts. But, in a strict and philosophical manner of speech, no man, no being, no mode of being, no any thing, can be the same with that with which it has indeed nothing the same. Now sameness is used in this latter sense when applied to persons. The identity of these, therefore, cannot subsist with diversity of substance.

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What personal identity is.

"The thing here considered, and demonstratively, as I think, determined, is proposed by Mr Locke in these words: Whether it (that is, the same self or person) be the same identical substance? And he has suggested what is a much better answer to the question than that which he gives it in form; for he defines a person a thinking intelligent being, &c. and personal identity, the sameness of a rational being; and then the question is, whether the same rational being is the same substance? which needs no answer; because being and substance are in this place synonymous terms. The ground of the doubt, whether the same person be the same substance, is said to be this, that the consciousness of our own existence in youth and in old age, or in any two joint successive moments, is not the same individual action, that is, not the same consciousness, but different successive consciousnesses. Now it is strange that this should have occasioned such perplexities; for it is surely conceivable that a person may have a capacity of knowing some object or other to be the same now which it was when he contemplated it formerly; yet in this case, where, by the supposition, the object is perceived to be the same, the perception of it in any two moments cannot be one and the same perception. And thus, though the successive consciousnesses which we have of our own existence are not the same, yet are they consciousnesses of one and the same thing or object; of the same person, self, or living agent. The person of whose existence the consciousness is felt now, and was felt an hour or a year ago, is discerned to be, not two persons, but one and the same person; and therefore is one and the same.

False notions of personal identity.

"Mr Locke's observations upon this subject appear hasty; and he seems to profess himself dissatisfied with the suppositions which he has made relating to it. But some of those hasty observations have been carried to a strange length by others, whose notion, when traced and examined to the bottom, amounts, I think, to this: 'That personality is not a permanent, but a transient thing; that it lives and dies, begins and ends, continually; that no one can any more remain one and the same person two moments together, than two successive moments can be one and the same moment; that our substance is indeed continually changing; but whether this be so or not, is, it seems, nothing to the purpose, since it is not substance, but consciousness alone, which constitutes personality; which consciousness, being successive, cannot be the same in any two moments, nor consequently the personality constituted by it."[2] Hence it must follow, that it is a fallacy upon ourselves to charge our present selves with any thing we did, or to imagine our present selves interested in any thing which befell us yesterday; or that our present self will be interested in what will befall us to-morrow; since our present self is not in reality the same with the self of yesterday, but another self or person coming in its stead, and mistaken for it; to which another self will succeed to-morrow. This, we say, must follow; for if the self or person of to-day and that of to-morrow are not the same, but only similar persons, the person of to-day is really no more interested in what will befall the person of to-morrow, than in what will befall any other person. It may be thought, perhaps, that this is not

[1] Dissertation First, subjoined to the Analogy of Religion, Natural and Revealed.
[2] Answer to Dr Clarke's third Defence of his Letter to Mr Dodwell, second edition, p. 44, 56, et seq.

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a just representation of the opinion we are speaking of, because those who maintain it allow that a person is the same as far back as his remembrance reaches; and indeed they employ the words identity and same person, nor will language permit these words to be laid aside. But they cannot, consistently with themselves, mean that the person is really the same; for it is self-evident, that the personality cannot be really the same, if, as they expressly assert, that in which it consists is not the same. "And as, consistently with themselves, they cannot," says Butler, "so I think it appears they do not, mean that the person is really the same, but only that he is so in a fictitious sense, in such a sense only as they assert; for this they do assert, that any number of persons whatever may be the same person. The bare unfolding this notion, and laying it thus naked and open, seems the best confutation of it. However, since great stress is said to be put upon it, I add the following things:

Butler's exposition.

"*First*, This notion is absolutely contradictory to that certain conviction, which necessarily and every moment rises within us, when we turn our thoughts upon ourselves, when we reflect upon what is past, and look forward to what is to come. All imagination of a daily change of that living agent which each man calls himself, for another, or of any such change throughout our whole present life, is entirely borne down by our natural sense of things. Nor is it possible for a person in his wits to alter his conduct with regard to his health or affairs, from a suspicion, that though he should live to-morrow, he should not however be the same person he is to-day.

"*Secondly*, It is not an idea or abstract notion, or quality, but a being only, which is capable of life and action, of happiness and misery. Now all beings confessedly continue the same during the whole time of their existence. Consider, then, a living being now existing, and which has existed for any time alive: this living being must have done, and suffered, and enjoyed, what it has done, and suffered, and enjoyed, formerly (this living being, I say, and not another), as really as it does, and suffers, and enjoys, what it does, and suffers, and enjoys this instant. All these successive actions, sufferings, and enjoyments, are actions, enjoyments, and sufferings, of the same living being; and they are so prior to all considerations of its remembering or forgetting, since remembering or forgetting can make no alteration in the truth of past matter of fact. And suppose this being endued with limited powers of knowledge and memory, there is no more difficulty in conceiving it to have a power of knowing itself to be the same being which it was some time ago, of remembering some of its actions, sufferings, and enjoyments, and forgetting others, than in conceiving it to know, or remember, or forget, any thing else.

"*Thirdly*, Every person is conscious that he is now the same person or self he was as far back as his remembrance reaches; since, when any one reflects upon a past action of his own, he is just as certain of the person who did that action, namely, himself (the person who now reflects upon it), as he is certain that the action was at all done. Nay, very often a person's assurance of an action having been done, of which he is absolutely assured, arises wholly from the consciousness that he himself did it; and this he, person, or self, must either be a substance or the property of some substance. If he, if person, be a substance, then consciousness that he is the same person, is consciousness that he is the same substance. If the person, or he, be the property of a substance, still consciousness that he is the same property is as certain a proof that his substance remains the same, as consciousness that he remains the same substance would be; since the same property cannot be transferred from one substance to another.

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"But though we are thus certain that we are the same agents, living beings, or substances, now, which we were as far back as our remembrance reaches, yet it is asked whether we may not possibly be deceived in it. And this question may be asked at the end of any demonstration whatever, because it is a question concerning the truth of perception by memory; and he who can doubt whether perception by memory can in this case be depended upon, may doubt also whether perception by deduction and reasoning, which also include memory, or indeed whether intuitive perception itself, can be depended upon. Here, then, we can go no farther; for it is ridiculous to attempt to prove the truth of our faculties, which can no otherwise be proved than by the use or means of those suspected faculties themselves."

Objections to this reasoning answered.

This reasoning, which we believe will to most men appear unanswerable, Mr Cooper hopes to overturn by the following observations:[1] "If all imagination of a daily change in us be borne down by our natural sense of things, then," says he, "does our natural sense of things positively contradict known fact; for a daily, a momentaneous, change in us, that is, in our bodies, does actually take place." True, a daily change in our bodies does take place, and so likewise does a daily change in our clothes; but surely no man was ever led by his natural sense of things to suppose that his limbs or external organs were the seats of sensation and will, any more than that his coat or his shoes were any real parts of his trunk or of his feet. But it is only that which thinks and wills that any man considers, in this case, as himself or his person; and if our natural sense of things, or consciousness, tells us, that what thinks and wills has continued the same from a distance of time as far back as we can remember, it is certain, that whether it be material or immaterial, it has continued from that period, otherwise we cannot be certain of any thing. "But," says our philosopher, "other known and ascertained facts are frequently borne down by our natural sense of things: For how many thousand years before the days of Copernicus was the motion of the earth round the sun entirely borne down by our natural sense of things, which made us give full credit to the motion of the sun round the earth? Do not the generality of mankind believe, upon the evidence of their natural sense of things, that every part of their body remains exactly the same to-day as it was yesterday?"

To the former of these questions we answer positively, that before the days of Copernicus the motion of the earth round the sun was not borne down by our natural sense of things, but by ill-founded hypotheses and inconclusive reasonings. By the natural sense of things, nothing can be meant, in this place, but the evidence of consciousness, or of external sensation; but the actual motion either of the sun or of the earth is not perceived either by consciousness or by sensation. Of consciousness nothing is the object but the internal energies and feelings of our own minds; and, with regard to the motion of the sun or of the earth, nothing is perceived by the sense of sight but that, after considerable intervals of time, these two great bodies have repeatedly changed their places in the heavens with respect to each other. This is all that on this subject our natural sense of things leads us to believe; and is not this infallibly true? Afterwards, indeed, by taking for granted the truth of propositions, for which neither sense nor consciousness affords the shadow of evidence, the vulgar now, and all mankind formerly, reasoned themselves into the opinion, that the earth stands still, and that the sun moves round it. In vulgar philosophy it is taken for grant-

[1] Tracts, &c.

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ed, that in the universe there is not a relative but an absolute upwards and an absolute downwards; that our heads are absolutely upward, and our feet downward; and that were the earth to revolve round its axis, these positions would be reversed, that our heads would be placed beneath our feet, and that we ourselves would fall from the earth into empty space. Upon these false hypotheses the vulgar reason correctly. They know that bodies cannot change their place without motion; they know that in the time of their remembrance the sun and the earth have been perpetually varying their places with respect to each other; they know that they themselves have never fallen, nor had a tendency to fall, into empty space; and hence they infer that it is the sun, and not the earth, that moves. But will any man say that the absurd suppositions from which this conclusion is logically deduced, have the evidence either of sensation or of consciousness, as the permanency of that living agent which each man calls himself has?

To our author's second question we likewise reply with confidence, that the generality of mankind do *not* believe, upon their natural sense of things, that every part of their body remains exactly the same to-day as it was yesterday. It would be strange indeed if they did, after having repeatedly experienced the waste of increased perspiration or sweating; after having witnessed men emaciated by sickness, and again restored to plumpness in health; and after having perhaps lost whole limbs, which certainly their natural sense of things teaches them to consider as parts of their body. In all these cases the generality of mankind are as sensible of changes having taken place in their bodies as he who has attended ever so closely to physiological inquiries, although not one of them has the least imagination of a change having taken place in the living agent which each man calls himself.

Bishop Butler observes, that if the living agent be perpetually changing, it is a fallacy upon ourselves to charge our present selves with any thing which we did, to imagine our present selves interested in any thing which befell us yesterday, or that our present self will be interested in what will befall us to-morrow. To this judicious observation our daring philosopher replies, "that as the man of to-morrow, though not in all points the same with, yet depends for his existence upon, the man of to-day, there is sufficient reason to care about him." Could he have said, that as the man of to-day depends for his existence on the man of to-morrow, there is sufficient reason for the present man to care about the future man; or that as the man of to-morrow depends for his existence on the man of to-day, there is to-day sufficient reason for the future man to care about the present man; we should, in either case, if the anachronism had been kept out of sight, have seen the force of his argument. Every man has sufficient reason to care about the ox upon which he is to be fed; but we cannot so clearly perceive what reason the ox has to care about the man.

Not satisfied, it would seem, with this reply, our author proceeds to affirm, "that the man of to-morrow, possessing a reminiscence of the actions of the man of to-day, and knowing that these actions will be referred to him both by himself and others (which is certainly knowing that both himself and others are most iniquitous wretches), they cannot be indifferent to the man of to-day, who looks forward to the properties of the man of to-morrow;" that is, the reminiscence and knowledge of a future man constitute all the relation that subsists between a present man and his actions, a discovery worthy of an original genius. But as on the subject of personal identity we pretend to no originality, we shall leave this proposition to the meditation of our readers, and take the liberty to ask our author a question or two respecting this same reminiscence, which he is graciously pleased to acknowledge as a property.

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He defines identity, "the continued existence of any being unaltered in substance or in properties;" and he repeatedly acknowledges that no identical quality or property can be transferred from one subject to another. Let us now suppose that a man has a reminiscence of an individual action performed a month ago, and that this reminiscence is accompanied with a consciousness that the action was performed by himself. This supposition, whether true or false, may certainly be made; for it implies nothing more than what every man firmly believes of himself in every act of remembrance. Let us again suppose, that, at the distance of ten or of twenty years, the man known by the same name has a reminiscence of the same action, with a consciousness that he himself performed it. Is this reminiscence the same with the former, or is it a different reminiscence? If it be the same, either the person remembering at the distance of ten or twenty years is the same with him who remembered at the distance of a month, or there is an identical quality transferred from one substance to another, which is admitted to be impossible. If reminiscence be itself a real and immediate quality of any substance, and not the mere energy of a power, and if the one reminiscence be different from the other, the subjects in which these two different qualities inhere must likewise be different. Yet the man who has the reminiscence at the distance of a month, has the evidence of consciousness that the action was performed by him; and the man who has the reminiscence at the distance of ten or twenty years, has likewise the evidence of consciousness that the same action was performed by him, and not by another. By the confession of Hume and of all philosophers, consciousness never deceives; but here is the evidence of one consciousness in direct opposition to another; and therefore, as two contradictory propositions cannot both be true, either the one reminiscence is the same with the other, or reminiscence is no real quality. That one act of reminiscence should be numerically the same with another which followed it at the distance of twenty years, is plainly impossible; whence it should seem, that reminiscence itself is no real and immediate quality of any substance. But if this be so, what is reminiscence? We answer, It is plainly neither more nor less than the energy of a power which, though dormant between its energies, remains unchanged from the one to the other, and which being itself the real and immediate quality of a subject, that subject must likewise remain unchanged. That powers may remain dormant, and yet unchanged, every man must be convinced, who, having struck any thing with his hand, knows that he has power to repeat the stroke, and yet does not actually repeat it. Two blows with the hand immediately following each other are numerically different, so that the one cannot with truth be said to be the other; but we have the evidence of external sense, that they are both struck by the same member. In like manner, two energies of reminiscence directed to the same object, and succeeding each other at any interval of time, cannot possibly be one and the same energy; but as the latter energy may include in it the former as well as the object remembered by both, we have the evidence of consciousness that both are energies of the same power; and we have seen, that to suppose them any thing else, may be demonstrated to involve the grossest absurdities and contradictions.

Mr Cooper has other arguments to obviate the force of Bishop Butler's demonstration of personal identity; such as, that a "high degree of similarity between the two succeeding men is sufficient to make the one care about the other; and, that "a good man, knowing that a future being will be punished or rewarded as the actions of the present man deserve, will have a sufficient motive to do right and

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to abstain from wrong." But if there be any one of our readers who can suffer himself to be persuaded by such assertions as these, that the living agent which he calls himself is perpetually changing, and at the same time that such change is consistent with the expectation of future rewards and punishments, he would not be reclaimed from his error by any reasoning of ours. We shall therefore trust such trifling to every man's judgment, and proceed to examine our author's demonstration, that personal identity has no existence. But here it is no part of our purpose to accompany him through his long chemical ramble, or to controvert his arguments for the non-identity of vegetable and animal bodies. The only thing to which, after Bishop Butler, we have ascribed identity, is that which in man is sentient and conscious; and the non-identity of this thing, whatever it be, Mr Cooper undertakes to demonstrate from the known properties of sensations and ideas.

Pretended demonstration that personal identity is impossible.

This demonstration sets out with a very ominous circumstance. The author, after conducting impressions *ab extra* from the extremities of the nerves to the brain, affirms, that sensations and ideas are nothing but "motions in the brain perceived;" that is, when a man thinks he is looking at a mountain, not only at rest, but to appearance immoveable, he is grossly deceived; for he perceives nothing all the while but motion in his brain. Were not the desire of advancing novelties and paradoxes invincible in some minds, we should be astonished at finding such an assertion as this fall from the pen of any man who had paid the slightest attention to the different energies of his own intellect. Motions in the brain, as we have repeatedly observed, are the immediate causes of our sensations; but is it conceivable, is it possible, that any thing should be the cause of itself? The motion of a sword through the heart of a man is the immediate cause of that man's death; but is the sword or its motion death itself, or can they be conceived as being the sensations of the man in the agonies of death? But sensations and ideas, whatever they be, exist in succession; and therefore, argues our demonstrator, no two sensations or ideas can be one and the same sensation or idea. The conclusion is logically inferred; but what purpose can it possibly serve? What purpose? Why, it seems "sensations and ideas are the only existences whose existence we certainly know (a charming phrase, the existence of existences, and as original as the theory in which it makes its appearance); and therefore, from the nature of sensations and ideas, there is no such thing as permanent identity. Indeed! what then, we may be permitted to ask, is the import of the word *we* in this sentence? Does it denote a series of sensations and ideas, and does each sensation and each idea certainly know not only itself, but all its ancestors and all its descendants? Unless this be admitted, we are afraid that some other existence besides sensations and ideas must be allowed to be certainly known, and even to have something of a permanent identity. Nay, we think it has been already demonstrated (see the Chapter on Time), that were there not something permanent, there could be no time, and of course no notion of a first and last, or indeed of succession, whether of sensations or ideas. And therefore, if we have such a notion, which the author here takes for granted, and upon which, indeed, his demonstration rests, it follows undeniably that there is something permanent, and that we know there is something permanent, which observes the succession of sensations and ideas.

This demonstration shown to be absurd.

All this, indeed, Mr Cooper in effect grants; for he is not much startled at the appearance of contradictions in his theory. "I find," says he, "by perpetually repeated impressions which I perceive; that my hands, body, limbs, &c. are connected, are parts of one whole. I find, by perpetually repeated perceptions, also, that the sensations excited by them are constantly similar, and constantly different from the sensations excited by others." He has, then, repeated perceptions; but how can this be possible, if he be not different from the perceptions, and if he do not remain unchanged whilst the perceptions succeed each other at greater or less intervals of time? A striking object passing with rapidity before the eyes of a number of men placed beside each other in a line of battle, would undoubtedly excite a succession of sensations; but surely that succession would not take place in the mind of any individual in the line, nor could any single man in this case say with truth that he had repeated perceptions of the object. In like manner, were that which is sentient perpetually changing, no man could possibly say or suppose that he had repeated perceptions of any thing; for, upon this supposition, the man of to-day would have no more connection with the man who bore his name yesterday, or twenty years ago, than the man in the line had with the first.

Upon the whole, we cannot help thinking that Bishop Butler's demonstration of personal identity remains unshaken by the batteries of Mr Cooper. It rests, indeed, upon the solid basis of consciousness and memory; and if implicit credit be not given to the evidence of these faculties, we cannot proceed a single step in any inquiry whatever, nor be certain of the truth even of a mathematical demonstration.

A difficulty removed.

But as we have ourselves supposed, that to sensation, reminiscence, and every actual energy of the mind of man, the instrumentality of some material system is necessary, it may perhaps be thought incumbent on us to show how the perpetual flux of the particles of matter which compose the brain, as well as all the other parts of the body, can consist with the identity of the person who perceives, remembers, and is conscious. If this cannot be done, our hypothesis, ancient and plausible as it is, must be given up; for of personal identity it is impossible to doubt. In this case, however, we perceive no difficulty; for if there be united to the brain an immaterial being, which is the subject of sensation, consciousness, and will, it is obvious that all the intellectual powers which properly constitute the person must be inherent in that being. The material system, therefore, can be necessary only as an instrument to excite the energies of those powers; and since the powers themselves remain unchanged, why should we suppose that their energies may not be continually exerted by successive instruments of the same kind, as well as by one permanent instrument? the powers of perception and volition are not in the material system, any more than the sensation of seeing is in the rays of light, or the energy of the blacksmith in the hammer with which he beats the anvil. Let us suppose a man to keep his eye for an hour steadily fixed upon one object. It will not surely be denied, that if this could be done, he would have one uninterrupted and unvaried perception of an hour's duration, as measured by the clock. Yet it is certain that the rays of light which alone could occasion that perception would be perpetually changing. In like manner, a blacksmith, whilst he continues to beat his anvil, continues to exert the same power, whether he uses one hammer all the time, or a different hammer at each stroke. The reason is obvious. The eye, with all its connections of brain and mind in the one case, and the person of the smith in the other, remain unchanged; and in them alone reside the faculty of sensation, and the power of beating, though neither the faculty nor the power can be exerted without material instruments. But were it possible that millions of men could in the space of an hour take their turns in rotation with each new ray of light, it is self-evident that in this case there would be nothing permanent in sensation; and therefore there could not be one uninterrupted and unvaried perception, but millions of perceptions, during the hour, totally distinct from and unconnected with each other. Let us now suppose a man

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to fix his eye upon an object for the space of a minute, and at the distance of a day or a month to fix it upon the same object a second time. He could not, indeed, in this case, have one uninterrupted and unvaried perception, but he would be conscious of the energy of the very same faculty the second time as well as the first. Whereas, were one man to view an object to-day, and another to view the same object to-morrow, it is obvious that he who should be last in the succession could know nothing of the energy of that faculty by which the object was perceived the first day, because there would not be any thing common to the two perceptions.

Thus, then, we see that personal identity may with truth be predicated of a compound being, though the material part be in a perpetual flux, provided the immaterial part remain unchanged; and that of such a being only is a resurrection from the dead possible. For since the motions of the brain do nothing more than excite to energy the permanent powers of the mind, it is of no sort of consequence to that energy whether there motions be continued by the same numerical atoms, or by a perpetual succession of atoms arranged and combined in the very same manner. We shall, therefore, be the same persons at the resurrection as at present, whether the mind be united to a particular system composed of any of the numberless atoms which have in succession made parts of our present bodies, or to a system composed of totally different atoms, provided that new system be organized in exactly the same manner with the brain or material vehicle which is at present the immediate instrument of perception. This, we say, is self-evident; but were the immaterial part to change with the changing body, a resurrection of the same persons would be plainly impossible.

CHAP. IV.—OF THE IMMORTALITY OF THE SOUL.

The immortality of the soul a general belief in all nations.

Wherever men have been in any degree civilized, and in some nations where they have been in the most savage state, it has been the general persuasion that the mind or soul subsists after the dissolution of the body. The origin of this persuasion, about which disputes have been raised, no Christian hesitates to attribute to revelation. The Egyptians, from whom the Greeks derived many of their theological and philosophical principles, appear to have taught the immortality of the soul, not as a truth discovered by the exertions of human reason, but as a dogma derived to them from the earliest ages by tradition. This indeed may be confidently inferred from the character and conduct of their first Greek disciples. Those early wise men who fetched their philosophy immediately from Egypt, brought it home as they found it, in detached and independent portions. Afterwards, when schools were formed, and when man began to philosophize by hypothesis and system, it was eagerly inquired upon what foundation in nature the belief of the soul's immortality could rest; and this inquiry gave rise to the various disquisitions concerning the substance of the soul, which have continued to exercise the ingenuity of the learned to the present day. It was clearly perceived, that if consciousness, thought, and volition, be the result of any particular modification of matter and motion, the living and thinking agent must perish with the dissolution of the system; and it was no less evident, that if the being which perceives, thinks, and wills, be not material, the mind of man may subsist after the resolution of the body into its component particles. The discovery of the immateriality of the mind was therefore one step towards the proof of its immortality; and, in the opinion of many philosophers, whose hopes ought to rest upon a surer basis, it was alone a complete proof. "They who hold sensitive perception in brutes," says a pious writer,[1] "to be an argument for the immateriality of their souls, find themselves under the necessity of allowing those souls to be immortal."

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The Greek philosophers believed in its pre-existence and absolute eternity.

The philosophers of ancient Greece, however, did not feel themselves under any such necessity. Whatever were their opinions respecting the souls of brutes, they clearly perceived that nothing which had a beginning of existence could be naturally immortal, whether its substance were material or immaterial. "There never was any of the ancients before Christianity," says the accurate Cudworth, "that held the soul's future permanency after death, who did not likewise assert its pre-existence; they clearly perceiving, that if it were once granted that the soul was generated, it could never be proved but that it might be also corrupted. And therefore, the assertors of the soul's immortality commonly began here, first to prove its preexistence, proceeding thence to establish its permanency after death. This is the method of proof used in Plato: "Our soul was somewhere before it came to exist in this human form, and thence it appears to be immortal, and as such will subsist after death."

To give this argument for immortality any strength, it must be taken for granted, not only that the soul existed in a prior state, but that it existed from all eternity; for it is obvious, that if it had a beginning in any state, it may have an end either in that state or in another. Accordingly, Plato asserts in plain terms its eternity and self-existence; which, as we learn from Cicero, he infers from its being the principle of motion in man. "Quin etiam cæteris, quæ moventur, hic fons, hoc principium est movendi. *Principii autem nulla est origo.* Nam ex principio oriuntur omnia: ipsum autem nulla ex re alia nasci potest: nec enim esset id principium, quod gigneretur aliunde."[2] This, it must be acknowledged, is very contemptible reasoning; but the opinion which it was intended to prove was held by all the philosophers. They were unanimous in maintaining the *substance* of the soul, though not its *personality*, to be eternal *a parte ante*, as well as *ad partem post;* and Cicero, where he tells us that this opinion passed from Pherecydes Syrus to Pythagoras, and from Pythagoras to Plato, expresses their notion of the soul's duration by the word *sempiternus;*[3] which, in its original and proper sense, is applicable only to that which has neither beginning nor end.

Indeed, none of the philosophers of ancient Greece appear to have believed a creation (see CREATION) possible; for it was a maxim universally received amongst them, *De nihilo nihil fit, in nihilum nil posse reverti*, that nothing can come from nonentity or go to nonentity. This maxim, as held by the theistical philosophers, the learned Cudworth labours to interpret in a sense agreeable to our notions of the origin of the world; but even the questions urged by himself must convince every competent reader that on this occasion he labours in vain. For instance, when Aristotle writes of Parmenides and Melissus, that "They say that no real entity is either made or destroyed," what can be his meaning, except that those philosophers taught that nothing could be either created or annihilated? He testifies the same thing of Xenophanes and Zeno, when he says that it was a fundamental principle of their philosophy, "That it is impossible that any thing should be made out of nothing;" and of Empedocles, when he relates, "That he acknowledges the very

[1] See the Procedure, Extent, and Limits of the Understanding.

[2] Quæst. Tuscul. lib. i. cap. xxiii.

[3] Quæst. Tuscul. lib. i.

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same thing with other philosophers, namely, that it is impossible that any thing should be made out of nothing, or perish into nothing." But it is needless to multiply quotations respecting the opinions of single philosophers. Of all the physiologers before himself and Plato, Aristotle says, without exception, "That they agree in this opinion, that it is impossible that any thing should be made out of nothing;"[1] and he calls this the common principle of naturalists, plainly intimating, that they considered it as the greatest absurdity to suppose that any real entity in nature could either be brought from nothing or reduced to nothing.

Eternity of matter, a principle of the ancient philosophy.

The author of the Intellectual System, in order, perhaps, to hide the impiety of this principle, endeavours to persuade his readers that it was urged only against the hypothesis of forms and qualities of bodies considered as real entities, distinct from matter. But how it could be supposed to militate against that particular opinion, and not against the possibility of all creation, is to us perfectly inconceivable. The father of the school which analyzed body into matter and form, together with by far the greater part of his followers, taught the eternity of both these principles, and therefore maintained, as strenuously as any atomist, the universal maxim, *De nihilo nihil fit.* Even Plato himself, whose doctrine of ideas is supposed to wear a more favourable aspect than Aristotle's forms, to the truths of revealed religion, taught the eternity of matter; but whether as a self-existing substance, or only as an emanation from the Deity, is a question which has been disputed. That he admitted no proper creation, may be confidently inferred from Plutarch, who, writing upon the generation of animals, according to the doctrine laid down in the Timæus, has the following passage: "It is therefore better for us to follow Plato, and to say and sing that the world was made by God. For as the world is the best of all works, so is God the best of all causes. Nevertheless, the substance or matter out of which the world was made, was not itself made, but was always ready at hand, and subject to the artificer, to be ordered and disposed by him. For the making of the world was not the production of it out of nothing, but out of an antecedent bad and disorderly state, like the making of a house, garment, or statue."[2]

If, then, this be a fair representation of the sentiments of Plato, and surely the author understood those sentiments better than the most accomplished modern scholar can pretend to do, nothing is more evident than that the founder of the academy admitted of no proper creation, but only taught that the matter which had existed from eternity in a chaotic state, was in time reduced to order by the Demiurgos or Supreme Being. And if such were the sentiments of the divine Plato, we cannot hesitate to adopt the opinion expressed by the excellent Mosheim, which the reader will probably be pleased to have in his own words: "Si a Judæis discedas, nescio an ullus antiquorum philosophorum mundum negaverit æternum esse. Omnes mihi æternum professi videntur esse mundum: hoc uno vero disjunguntur, quod nonnulli ut Aristoteles, formam et materiam simul hujus orbis, alii vero, quorum princeps facile Plato, materiam tantum æternam, formam vero, a Deo comparatam, dixerunt."[3]

Now, it is a fact so generally known, as not to stand in need of being proved by quotations, that there was not amongst them a single man who believed in the existence of mind as a being more excellent than matter, and essentially different from it, who did not hold that the superior was at least of equal antiquity with the inferior substance. So true is this, that Synesius, though a Christian, yet having been educated in one of the schools of philosophy, could not be induced, even by the hopes of a bishopric, to dissemble this sentiment: "I shall never be persuaded to think my soul younger than my body."[4] This man probably believed, upon the authority of the Scriptures, that the matter of the visible world was created in time; but he certainly held, with his philosophic masters, that his own soul was as old as any atom of it, and that it had consequently existed in a prior state before it animated his present body.

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The ancients supposed all souls emanations of the first Mind.

Those who maintained that the world was uncreated, maintained upon the same principle that their souls were likewise uncreated; and as they conceived that all bodies were formed of one first matter, so they conceived all souls to be either emanations from the one first Mind, or discerpted parts of it. Aristotle, who distinguishes between the intellectual and the sensitive souls, says expressly of the former, that it "enters from without, and is divine;" adding this reason for his opinion, that "its energy is not blended with that of the body."[5] As to the Stoics, Cleanthes held, as Stobæus informs us,[6] that "every thing was made out of one, and would again be resolved into one." But let Seneca speak for them all. "Quid est autem, cur non existimes in eo divini aliquid existere, qui Dei pars est? Totum hoc, quo continemur, et unum est, et Deus: et socii ejus sumus, et membra."[7] "Why should you not believe something to be divine in him, who is indeed part of God? That whole in which we are contained is one, and that one is God; we being his companions and members." Epictetus says, "The souls of men have the nearest relation to God, as being parts or fragments of him, discerpted and torn from his substance." Plato writes to the very same purpose, when, without any softening, he frequently calls the soul God, and part of God. And Plutarch says, that "Pythagoras and Plato held the soul to be immortal; for that, launching out into the soul of the universe, it returns to its parent and original."[8] He, at the same time, declares his own opinion to be, that "the soul is not so much the work and production of God, as a part of him; nor is it made by him, but from him and out of him."[9] But it is needless to multiply quotations. Cicero delivers the common sentiments of his Greek masters on this head, when he says,[10] "A natura deorum, ut doctissimis sapientissimisque placuit, haustos animos et libatos habemus." And again: "Humanus autem animus decerptus ex mente divina: cum alio nullo, nisi cum ipso Deo (si hoc fas est dictu), comparari potest."

They differed as to the mode of separation.

Whilst the philosophers were thus unanimous in maintaining the soul to be a part of the self-existent substance, they differed in opinion, or at least expressed themselves differently, as to the mode of its separation from its divine parent. Cicero and the Stoics talk as if the Supreme Mind were extended, and as if the human soul were a part literally torn from that mind, as a limb can be torn from the body. The Pythagoreans and Platonists seem to have considered all souls as emanations from the divine substance rather than as parts torn from it, much in the same way as rays of light are emanations from the sun. Plato, in particular, believed in two self-existent principles, namely, God and matter. The former he considered as the Supreme Intelligence, incorporeal, without beginning, end, or change; and distinguished it by the appellation of τὸ ἀγαθὸν, *the Good.* Matter, as subsisting from eternity, he

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[1] *Physic.* lib. i. cap. v.
[2] Plut. *Op.* tom. ii. p. 1014.
[3] Notes on Cudworth's Intellectual System.
[4] *Epist.* 105.
[5] *De Generatione Animalium*, lib. ii. cap. iii.
[6] *Eclog. Phys.* c. xx.
[7] *Epist.* 92.
[8] *De Placitis Philosophorum*, lib. iv. cap. vii.
[9] Plato, *Quæst.*
[10] *De Divinatione*, lib. i. cap. xlix.

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considered as without any one form or quality whatever, and as having a natural tendency to disorder. Of this chaotic mass God formed a perfect world, after the eternal pattern in his own mind, and endowed it with a soul or emanation from himself. In the language of Plato, therefore, the universe, being animated by a soul which proceeds from God, is called the son of God; and several parts of nature, particularly the heavenly bodies, are gods. The human soul, according to him, is derived by emanation from God, through the intervention of this soul of the world; and receding farther from the first intelligence, it is inferior in perfection to the soul of the world, though even that soul is debased by some material admixture. To account more fully for the origin and present state of human souls, Plato supposes,[1] that "when God formed the universe, he separated from the soul of the world inferior souls, equal in number to the stars, and assigned to each its proper celestial abode; but that those souls (by what means, or for what reason, does not appear) were sent down to the earth into human bodies, as into sepulchres or prisons." He ascribes to this cause the depravity and misery to which human nature is liable, and maintains, that it "is only by disengaging itself from all animal passions, and rising above sensible objects to the contemplation of the world of intelligence, that the soul of man can be prepared to return to its original state." Not inconsistently with this doctrine, the same philosopher frequently speaks of the soul of man as consisting of three parts, or rather he seems to have thought that man has three souls; the first the principle of intelligence, the second of passion, and the third of appetite; and to each he assigns its proper place in the human body. But it was only the intellectual soul that he considered as immortal.

Aristotle taught, in terms equally express, that the human soul is a part of God, and of course that its substance is of eternal and necessary existence. Some of his followers, indeed, although they acknowledged two first principles, the active and the passive, yet held, with the Stoics, but one substance in the universe; and to reconcile these two contradictory propositions, they were obliged to suppose matter to be both active and passive. Their doctrine on this subject is thus delivered by Cicero: "De natura ita dicebant, ut eam dividerent in res duas, ut altera esset efficiens, altera autem quasi huic se præbens, ea quæ efficeretur aliquid. In eo, quod efficeret, vim esse censebant; in eo autem quod efficeretur, materiam quandam; in *utroque tamen utrumque.* Neque enim materiam ipsam coherere potuisse, si nulla vi contineretur, neque *vim sine aliqua materia;* nihil est enim, quod non alicubi esse cogatur."[2] "They divided nature into two things, as the first principles; one of which is the efficient or artificer, the other that which offers itself to him for things to be made out of it. In the efficient principle, they acknowledged active force; in the passive, a certain matter; but so that in *each both of these were together;* forasmuch as neither the matter could cohere together unless it were contained by some active force, nor *the active force subsist of itself without matter;* because that is nothing which may not be compelled to be somewhere." Agreeably to this strange doctrine, Arrian, the interpreter of Epictetus, says of himself, "I am a man (a part of the το παν, or *universe*), as an hour is part of the day."

Aristotle himself is generally supposed to have believed in the eternal existence of two substances, mind and matter; but, treating of the generation of animals, he says,[3] "In the universe there is a certain animal heat, so that after a manner all things are full of mind; wherefore they are quickly completed (or made complete animals) when they have received a portion of that heat." This heat, from which, according to Cicero,[4] the Stagyrite derived all souls, has, it must be confessed, a very material appearance; insomuch that the learned Mosheim seems to have been doubtful whether he admitted of any immaterial principle in man. But for this doubt there appears to us to be no solid foundation. Aristotle expressly declares, that "this heat is not fire, nor any such power, but a spirit which is in the seeds or elementary principles of bodies."[5] And as the excellent person himself acknowledges that Aristotle taught the existence of two principles, God and matter, not indeed subsisting separately, but eternally linked together by the closest union, we think it follows undeniably, that this heat, from which he derived all souls, must be that mind which he called God, and which he considered as the actuating soul of the universe.

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Upon these principles neither Aristotle nor the Stoics could believe, with Plato, that in the order of nature there was first an emanation from the Supreme Mind to animate the universe, and then through this universal soul other emanations to animate mankind. The Stagyrite believed that the Supreme Mind himself is the soul of the world, and that human souls are immediately derived from him. The genuine Stoics, acknowledging but one substance, of necessity considered both the souls and bodies of men as portions of that substance, which they called το ὂν; though still they affected to make some unintelligible distinction between body and mind. But, however the various schools differed as to those points, they were unanimous as to the soul's being a part of the self-existing substance; and Cicero gives their whole system from Pacuvianus, in words which cannot be misunderstood:

They maintained the necessary but not distinct existence of the soul.

> Quicquid est hoc, omnia animat, format, alit, auget, creat,
> Sepelit, recipitque in sese omnia, omniumque idem est Pater:
> Indidemque eadem, quæ oriuntur de integro, atque eodem occidunt.

To these verses he immediately subjoins the following query: "Quid est igitur, cur, cum domus sit omnium una, eaque communis, cumque animi hominum *semper fuerint, futurique sint,* cur ii, quid ex quoque eveniat, et quid quamque rem significet, perspicere non possint?"[6] And upon the same principle he elsewhere argues, not merely for the immortality, but for the eternity and necessary existence, of the soul: "Animorum nulla in terris origo inveniri potest: His enim in naturis nihil inest, quod vim memoriæ mentis, cogitationis habeat; quod et præterita teneat, et futura provideat, et complecti possit præsentia; quæ sola divina sunt. Nec invenietur unquam, unde ad hominem venire possint, nisi a Deo. Ita quicquid est illud, quod sentit, quod sapit, quod vult, quod viget, cæleste et divinum est; *ob eamque rem æternum sit necesse est.*"[7] This was indeed securing the future permanency of the soul in the most effectual manner; for it is obvious, that what had not a beginning can never have an end, but must be of eternal and necessary existence. But when the ancients attributed a proper eternity to the soul, we must not suppose that they understood it to be eternal in its distinct and personal existence. They believed that it proceeded or was discerpted in time from the substance of God, and would in time be again resolved into that substance. This they explained by a close vessel filled with sea-water, which, swimming a while upon the ocean, does, upon the vessel's breaking, flow in again, and mingle with the common mass.

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1 Enfield's Abridgement of Brucker's History of Philosophy.
2 *Academica*, lib. i. cap. vi.
3 *De Generatione Animalium*, lib. iii. cap. xi.
4 *Tuscul.* lib. i. cap. iii.
5 *De Generatione Animalium*, lib. ii. cap. iii.
6 *De Divinatione*, lib. i. p. 57.
7 *Frag. de Consolatione.*

Of the Immortality of the Soul.

They only differed about the time of this re-union; the greater part holding it to be at death, but the Pythagoreans not till after many transmigrations. The Platonists went between these two opinions, and rejoined pure and unpolluted souls immediately to the Universal Spirit; but those which had contracted much defilement were sent into a succession of other bodies, to be purged and purified, before they returned to their parent substance.[1]

A similar doctrine held by the Brahmins.

A doctrine similar to this of Plato has been held from time immemorial by the Brahmins in India, whose sacred books teach, "That intellect is a *portion* of the *Great Soul* of the universe, breathed into all creatures, to animate them for a certain time; that after death it animates other bodies, or returns like a drop into that unbounded ocean from which it first arose; that the souls of men are distinguished from those of other animals, by being endowed with reason and with a consciousness of right and wrong; and that the soul of him who adheres to right as far as his powers extend, is at death *absorbed into that divine essence*, never more to re-animate flesh. On the other hand, the souls of those who do evil are not at death disengaged from all the elements, but are immediately clothed with a body of fire, air, and *akash* (a kind of celestial element, through which the planets move, and which makes no resistance), in which they are for a time punished in hell. After the season of their grief is over, they re-animate other bodies; and when they arrive through these transmigrations at a state of purity, they are absorbed into God, where all *passions* are *utterly unknown*, and where *consciousness is lost in bliss*."[2]

Incompatible with a future state.

Whether the Greeks derived their notions of the divinity and transmigration of souls from the east, or whether both they and the Brahmins brought the same doctrines at different periods from Egypt, it is foreign to the purpose of this article to inquire. Certain it is, that the philosophers of Greece and India argued in the very same manner, and upon the very same principles, for the natural immortality of the soul; and that the immortality which they taught was wholly incompatible with God's moral government of the world, and with a future state of rewards and punishments. That this is true of the doctrine of the Brahmins, is evident from the last-quoted sentence; for if the soul, when absorbed into the Divine essence, loses all consciousness of what it did and suffered in the body, it cannot possibly be rewarded for the virtues it practised upon earth. That the philosophers of Greece taught the same cessation of consciousness, might be inferred with the utmost certainty, even though we had not Aristotle's express declaration to that purpose. For as they all believed their souls to have existed before these were infused into their bodies, and as each must have been conscious that he remembered nothing of his former state, it was impossible to avoid concluding, that in the future state of his soul as little would be remembered of the present. Accordingly Aristotle teaches, that "the active intellect only is immortal and eternal, but the passive corruptible."[3] Cudworth thinks this a very doubtful and obscure passage; but Warburton, whose natural acuteness often discovered the sense of ancient authors when it had escaped the sagacity of abler scholars, has completely proved, that by the active intellect is meant the substance of the soul, and by the passive its particular perceptions. It appears therefore that the Stagyrite, from the common principle of the soul's being a part of the Divine substance, draws a conclusion against a future state of rewards and punishments; which, though all the philosophers, except Socrates, embraced, yet all were not so forward to avow.

That the hypothesis of the soul's being a part of the Divine substance is a gross absurdity, we surely need not spend time in proving. The argument long ago urged against it by St Augustin must ere now have occurred to every reader. In the days of that learned father of the church, it was not wholly given up by the philosophers; and, in his excellent work of the City of God, he thus exposes its extravagance and impiety: "Quid infelicius credi potest, quam Dei partem vapulare, cum puer vapulat? Jam vero partes Dei fieri lascivas, iniquas, impias, atque omnino damnabiles, quis ferre potest nisi qui prorsus insanit?"

Of the Immortality of the Soul.

Grossly absurd in itself.

Yet it is the only principle from which the soul can be inferred to be immortal.

But although this hypothesis be in the highest degree absurd, and wholly untenable, we apprehend it to be the only principle from which the natural or essential immortality of the soul can possibly be inferred. If the soul had a beginning, it may have an end; for nothing can be more evident, than that the being which had not existence of itself, cannot of itself have perpetuity of existence. Human works, indeed, continue in being after the power of the workman is withdrawn from them; but between human works and the Divine there is this immense difference, that the former receive from the artist nothing but their form, whereas the latter receive from the Creator both their form and their substance. Forms are nothing but modifications of substance; and as substances depend upon God and not upon man, human works are continued in being by that fiat of the Creator, which made the substances of which they are composed susceptible of different forms, and of such a nature as to retain for a period of time whatever form may be impressed upon them. Human works, therefore, are continued in being by a power different from that by which they are finished; but the works of God depend wholly upon that power by which they were originally brought into existence; and were the Creator to withdraw his supporting energy, the whole creation would sink into nothing.

Baxter's argument for the immortality of the soul inconclusive.

Self-evident as this truth certainly is, some eminent philosophers seem to have questioned it. "No substance or being," says Mr Baxter,[4] "can have a natural tendency to annihilation, or to become nothing. That a being which once exists should cease to exist, is a real effect, and must be produced by a real cause. But this could not be planted in the nature of any substance or being to become a tendency of its nature; for it could not be a free cause, otherwise it must be a being itself, the subject of the attribute freedom, and therefore not the property of another being, nor a necessary cause, for such a cause is only the effect of something imposing that necessity, and so no cause at all."

That the author's meaning in this argument is good, cannot, we think, be controverted; but assuredly he has not expressed himself with his usual accuracy. He seems to confound causes with the absence of causes, and the effects of the former with the consequences of the latter. The visible world was brought into existence by the actual energy of the power of God; and as the visible world had nothing of itself, it can remain in existence only by a continuance of the same energy. This energy, therefore, is at the present moment as real a cause as it was six thousand years ago, or at any period when it may have been first exerted; and the visible world is its real and permanent effect. But would the ceasing of this energy be likewise a cause? It would certainly be followed by the annihilation of the visible world, just as the withdrawing of the sunbeams would be followed by darkness on the earth. Yet as no one has ever supposed that darkness,

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[1] Warburton's Divine Legation.
[2] See Preliminary Dissertation to Dow's History of Hindustan.
[3] *De Anima*, lib. iii. cap. vi.
[4] Inquiry into the Nature of the Human Soul, vol. i. sect. 3.

Of the Immortality of the Soul.

a nonentity, is a positive effect of the sun or of his beams, but only a mere negative consequence of their absence; so, we think, no one who believes in creation can consider that destruction which would inevitably follow the withdrawing of the energy by which all things are supported, as the positive effect of a contrary energy, or as any thing more than a negative consequence of the ceasing of that volition or energy of power by which God at first brought things into existence. For "where the foundation of existence lies wholly in the power of an infinite being producing, the ground of the continuance of that existence must be wholly in the same power conserving; which has, therefore, with as much truth as frequency, been styled a continued creation."[1]

The force of this reasoning Mr Baxter certainly saw, when he said, that "a tendency to persevere in the same state of nature, and a tendency to change it, are contradictories, and impossible to be planted in the same subject at once; or, not to urge the contradiction, if the last prevailed, the remaining in the same state for any given time would be impossible. We forget the true cause of all these tendencies, the will of God, which it is absurd to suppose contrary to itself. The tendency in matter to persevere in the same state of rest or motion, is nothing but the will of the Creator, who preserves all things in their existence and manner of existence; nor can we have recourse to any other cause for the preservation of immaterial substance in its existence. Therefore these tendencies are to be ascribed to the will of God, and it is absurd to suppose them contrary."

Analogical evidence.

All this is unquestionably true. The existence or non-existence of matter and of created spirits depends wholly upon the will of God; and we cannot suppose him to be willing to-day the reverse of what he willed yesterday, because we know that all his volitions are directed by unerring wisdom. We have likewise the evidence of experience, that nothing is ever suffered to perish except particular systems, which perish only as systems by a decomposition of their parts. A being which, like the soul, has no parts, can suffer no decomposition; and therefore, if it perish, it must perish by annihilation. But of annihilation there has not hitherto been a single instance; nor can we look for a single instance, without supposing the volitions of God to partake of that unsteadiness which is characteristic of man. Corporeal systems, when they have served their purpose, are indeed resolved into their component parts; but the matter of which they were composed, so far from being lost, becomes the matter of other systems in endless succession. Analogy, therefore, leads us to conclude, that when the human body is dissolved, the immaterial principle by which it was animated will continue to think and act, either in a state of separation from all body, or in some material vehicle to which it is intimately united, and which goes off with it at death; or else that it will be preserved by the Father of Spirits, for the purpose of animating a body in some future state. When we consider the different states through which that living and thinking individual, which each man calls himself, goes, from the moment that it first animates an embryo in the womb, to the dissolution of the man of fourscore; and when we reflect likewise on the wisdom and immutability of God, together with the various dissolutions of corporeal systems, in which we know that a single atom of matter has never been lost; the presumption is certainly strong, that the soul shall subsist after the dissolution of the body. But when we take into the consideration the moral attributes of God, his justice and goodness, together with the unequal distribution of happiness and misery in the present world, this presumption from analogy amounts to a complete moral proof that there shall be a future state of rewards and punishments; and if we estimate the duration of the rewards by the benevolence of him by whom they are to be conferred, we cannot imagine them shorter than eternity.

Of Necessity and Liberty.

CHAP. V.—OF NECESSITY AND LIBERTY.

Free agency implied in accountableness.

In the preceding chapter, we have adverted to that great moral proof of a future state, and the immortality of the soul, which arises from the relation in which man, as a being accountable for his conduct, stands to a God of almighty power, infinite wisdom, and perfect justice. But the circumstance of accountableness implies freedom of agency; for it is contrary to all our notions of right and wrong that a man should be either rewarded or punished for actions which he was necessitated or compelled to perform.

Every man has power to do what he wills.

Human actions are of three kinds: One where we act by instinct, without any view to consequences; one where we act by will, in order to obtain some end; and one where we act against will. It is the second kind of actions only which confers upon the agent merit or demerit. With respect to the first, he acts blindly (see INSTINCT), without deliberation or choice; and the external act follows from the instinctive impulse, no less necessarily than a stone by its gravity falls to the ground. With respect to the last, he is rather an instrument than an agent; and it is universally allowed, that were a strong man to put a sword into the hand of one who is weaker, and then to force it through the body of a third person, he who held the sword would be as guiltless of the murder as the sword itself. To be entitled to rewards, or liable to punishment, a man must act voluntarily; or, in other words, his actions must proceed from that energy of mind which is termed volition; and we believe it has never been denied, that all men have power to do whatsoever they will, both with respect to the operations of their minds and to the motions of their bodies, uncontrolled by any foreign principle or cause. "Every man," says Dr Priestley, "is at liberty to turn his thoughts to whatever subject he pleases, to consider the reasons for or against any scheme or proposition, and to reflect upon them as long as he shall think proper; as well as to walk wherever he pleases, and to do whatever his hands and other limbs are capable of doing." Without such liberty as this, morality is inconceivable.

Different opinions as to the freedom of volition.

But although philosophers have in general agreed with respect to the power which a man has to perform such actions as he wills, they have differed widely in opinion respecting the nature of his volitions. That these are the result of motives, has seldom or never been questioned; but whether that result be necessary, so that the agent possesses no self-determining power to decide between different motives, has been warmly disputed by men equally candid, impartial, and intelligent. The principal writers on the side of necessity are, Hobbes, Collins, Hume, Leibnitz, Lord Kames, Hartley, Edwards, Priestley, and perhaps Locke. On the other side are, Clarke, King, Law, Reid, Butler, Price, Bryant, Wollaston, Horsley, Beattie, and Gregory. To give a short view of this celebrated question is all that our limits will permit; and as we do not think ourselves competent to settle the dispute, it were perhaps a thing desirable to give the opposite reasonings in the words of those eminent authors themselves. It

[1] See Stillingfleet's *Origines Sacræ*, where this question is treated in a very masterly manner, by one of the ablest metaphysicians of the seventeenth century.

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must, however, be obvious to the reader, that the style and manner of so many different writers are extremely various, and that to introduce them all into our abstract would render the whole a mass of confusion. We shall, therefore, select one writer to plead the cause of necessity, supplying his defects from those who, though inferior to him on the whole, may yet have argued more ably on some particular points which the question involves; and to this combined reasoning we shall subjoin such answers as to us appear most conclusive. Hartley, Hume, and Priestley, are perhaps the most profound reasoners on the side of necessity; but there is so much more perspicuity in the arguments of Lord Kames, that we cannot help preferring them, as being upon the whole better calculated to give the ordinary reader a fair view of the subject.

Kames' scheme of necessity.

"Into actions done with a view to an end," says his lordship,[1] "desire and will enter; desire to accomplish the end goes first; the will to act, in order to accomplish the end, is next; and the external act follows of course. It is the will, then, that governs every external act done as a mean to accomplish an end; and it is desire to accomplish the end that puts the will in motion; desire, in this view, being commonly termed the motive to act. But what is it that raises desire? The answer is ready: It is the prospect of attaining some agreeable end, or of evading one that is disagreeable. And if it be inquired, what makes an object agreeable or disagreeable? the answer is equally ready: It is our nature that makes it so. Certain visible objects are agreeable, certain sounds and certain smells: other objects of these senses are disagreeable. But there we must stop, for we are far from being so intimately acquainted with our own nature as to assign the causes.

"With respect to instinctive actions, no person, I presume, thinks that there is any freedom. With respect to voluntary actions, done in order to produce some effect, the necessity is the same, though less apparent at first view. The external action is determined by the will, the will is determined by desire, and desire by what is agreeable or disagreeable. Here is a chain of causes and effects, not one link of which is arbitrary, or under command of the agent: he cannot will but according to his desire; he cannot desire but according to what is agreeable or disagreeable in the objects perceived: nor do these qualities depend on his inclination or fancy; he has no power to make a beautiful woman ugly, nor to make a rotten carcass smell sweetly.

"Many good men, apprehending danger to morality from holding our actions to be necessary, endeavour to break the chain of causes and effects above mentioned; maintaining, that whatever influence desire or motives may have, it is the agent himself who is the cause of every action; that desire may advise, but cannot command; and, therefore, that a man is still free to act in contradiction to desire and to the strongest motives.

"That a being may exist which in every case acts blindly and arbitrarily, without having any end in view, I can make a shift to conceive; but it is difficult for me even to imagine a thinking and rational being, that has affections and passions, that has a desirable end in view, that can easily accomplish this end, and yet after all can fly or remain at rest, without any cause, reason, or motive, to sway it. If such a whimsical being can possibly exist, I am certain that man is not that being. There is not, perhaps, a person above the condition of a changeling but can say why he did so and so, what moved him, what he intended. Nor is a single fact stated to make us believe that ever a man acted against his own will or desire who was not compelled by external force. On the contrary, constant and universal experience proves that human actions are governed by certain inflexible laws; and that a man cannot exert his self-motive power but in pursuance of some desire or motive.

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"Had a motive always the same influence, actions proceeding from it would appear no less necessary than the actions of matter. The various degrees of influence that motives have on different men at the same time, and on the same man at different times, occasion a doubt, by suggesting a notion of chance. Some motives, however, have such influence as to leave no doubt: a timid female has a physical power to throw herself into the mouth of a lion roaring for food, but she is withheld by terror no less effectually than by cords: if she should rush upon a lion, would not every one conclude that she was frantic? A man, though in a deep sleep, retains a physical power to act, but he cannot exert it. A man, though desperately in love, retains a physical power to refuse the hand of his mistress; but he cannot exert that power in contradiction to his own ardent desire, more than if he were fast asleep. Now, if a strong motive have a necessary influence, there is no reason for doubting but that a weak motive must also have its influence, the same in kind, though not in degree. Some actions, indeed, are strangely irregular; but let the wildest actions be scrutinized, there will always be discovered some motive or desire, which, however whimsical or capricious, was what influenced the person to act. Of two contending motives, is it not natural to expect that the stronger will prevail, however little its excess may be? If there be any doubt, it must arise from a supposition that a weak motive may be resisted arbitrarily. Where, then, are we to fix the boundary between a weak and a strong motive? If a weak motive can be resisted, why not one a little stronger, and why not the strongest? Between two motives opposing each other, however nearly balanced, a man has not an arbitrary choice, but must yield to the stronger. The mind, indeed, fluctuates for some time, and finds itself in a measure loose: at last, however, it is determined by the more powerful motive, as a balance is by the greater weight after many vibrations.

"Such, then, are the laws that govern our voluntary actions. A man is absolutely free to act according to his own will; greater freedom than which is not conceivable. At the same time, as man is made accountable for his conduct to his Maker, to his fellow-creatures, and to himself, he is not left to act arbitrarily; for at that rate he would be altogether unaccountable: his will is regulated by desire, and desire by what pleases or displeases him. Thus, with regard to human conduct, there is a chain of laws established by nature, no one link of which is left arbitrary. By that wise system, man is made accountable; by it he is made a fit subject for divine and human government; by it persons of sagacity foresee the conduct of others; by it the prescience of the Deity with respect to human actions is clearly established."

Of the doctrine of necessity, a more perspicuous or plausible view than this is not to be found in any work with which we are acquainted. It is indeed defective, perhaps, as his lordship only hints at the nature of that relation which subsists between motive and action; but, from his comparing the fluctuations of the mind between two contending motives, to the vibrations of a balance with different weights in the opposite scales, there is no room to doubt but that he agreed exactly in opinion with Mr Hume and Dr Priestley.

Mr Hume and Dr Priestley.

Now, both these writers hold, that the relation of motives to volition and action is the very same with that which subsists between cause and effect in physics, as far as they are both known to us. "It is universally allowed," says

[1] Sketches of the History of Man, book iii. sketch ii. part i. sect. 8.

Of Necessity and Liberty.

Mr Hume,[1] "that matter, in all its operations, is actuated by a necessary force; and that every natural effect is so precisely determined by the energy of its cause, that no other effect, in such particular circumstances, could possibly have resulted from it. The degree and direction of every motion is, by the laws of nature, prescribed with such exactness, that a living creature may as soon arise from the shock of two bodies, as motion in any other degree or direction than what is actually produced by it. Would we, therefore, form a just and precise idea of necessity, we must consider whence that idea arises when we apply it to the operation of bodies. But our idea of this kind of necessity and causation arises entirely from the uniformity observable in the operations of nature, where similar objects are constantly conjoined together, and the mind is determined by custom to infer the one from the appearance of the other. These two circumstances form the whole of that necessity which we ascribe to matter. Beyond the constant conjunction of similar objects, and the consequent inference from one to the other, we have no notion of any necessity or connection." He then gives a pretty long detail to prove a great uniformity among the actions of men in all nations and ages; and concludes that part of his argument with affirming, "not only that the conjunction between motives and voluntary actions is as regular and uniform as that between the cause and effect in any part of nature; but also, that this regular conjunction has been universally acknowledged among mankind, and has never been the subject of dispute either in philosophy or common life." He afterwards observes, "That men begin at the wrong end of this question concerning liberty and necessity, when they enter upon it by examining the faculties of the soul, the influence of the understanding, and the operations of the will. Let them first discuss a more simple question, namely, the operations of body, and of brute unintelligent matter, and try whether they can there form any idea of causation and necessity, except that of a constant conjunction of objects, and subsequent inference of the mind from one to another. If these circumstances form in reality the whole of that necessity which we conceive in matter, and if these circumstances be also universally acknowledged to take place in the operations of the mind, the dispute is at an end; at least must be owned to be thenceforth merely verbal. When we consider how aptly natural and moral evidence link together, and form only one chain of argument, we shall make no scruple to allow that they are of the same nature, and derived from the same principles. Between a connected chain of natural causes and voluntary actions, the mind feels no difference in passing from one link to another; nor is less certain of a future event which depends upon motives and volitions, than if it were connected with the objects present to the memory and senses by a train of causes, cemented together by what we are pleased to call a physical necessity. The same experienced union has the same effect on the mind, whether the united objects be motives, volition and action, or figure and motion. We may change the names of things, but their nature and their operation on the understanding never change."

Dr Priestley, in words a little different, teaches the very same doctrine which was taught by Mr Hume. "In every determination of the mind," says he,[2] "or in cases where volition and choice are concerned, all the previous circumstances to be considered are the state of mind (including every thing belonging to the will itself), and the views of things presented to it; the latter of which is generally called the motive, though under this term some writers comprehend them both. To distinguish the manner in which events depending upon will and choice are produced, from those in which no volition is concerned, the former are said to be produced voluntarily, and the latter mechanically. But the same general maxims apply to them both. We may not be able to determine *a priori* how a man will act in any particular case; but it is because we are not particularly acquainted with his disposition of mind, precise situation, and views of things. But neither can we tell in which way the wind will blow to-morrow, though the air is certainly subject to no other than necessary laws of motion.

"It is universally acknowledged, that there can be no effect without an adequate cause. This is even the foundation on which the only proper argument for the being of a God rests. And the necessarian asserts, that if, in any given state of mind, with respect both to disposition and motives, two different determinations or volitions be possible, it can be so on no other principle, than that one of them shall come under the description of an effect without a cause; just as the beam of a balance might incline either way, though loaded with equal weights. It is acknowledged, that the mechanism of the balance is of one kind, and that of the mind of another; and, therefore, it may be convenient to denominate them by different words; as, for instance, that of the balance may be termed a physical, and that of the mind a moral mechanism. But still, if there be a real mechanism in both cases, so that there can be only one result from the same previous circumstances, there will be a real necessity, enforcing an absolute certainty in the event. For it must be understood, that all that is ever meant by necessity in a cause, is that which produces certainty in the effect."

View of human liberty.

Such is the nature of human volitions, according to every necessarian of eminence who has written upon the subject since the days of Hobbes; and if this theory be just, if there be a constant and inseparable conjunction of motives and actions similar to that of cause and effect in physics, it is obvious, that in volition the mind is as inert as body is in motion. This consequence is indeed avowed and insisted upon by Hume, Priestley, and their adherents; whilst the advocates of human liberty, on the other hand, contend for an absolute exemption of the will from all internal necessity, arising from its own frame and constitution, the impulse of superior beings, or the operations of objects, reasons, or motives. By this, however, they do not mean, that between motives and volitions there is no relation whatever, or that a man can ever choose evil as evil, or refuse good as good. Such an assertion would be contrary to consciousness and universal experience. But what they endeavour to prove is, that the conjunction of motive and volition is not inseparable, like that of cause and effect in physics; that a man may in most cases choose according to any one of two or more motives presented to his view; that by choosing any thing, he may make it in some measure agreeable by his own act, or, to speak more properly, may bend his desire to it; that in volition, the mind is not inert; and that, therefore, we are under no necessity to act in a particular manner in any given case whatever.

That the conjunction of motive and action is not constant like that of cause and effect in physics, and that by consequence the mind in forming volitions is not inert, has been evinced by Dr Gregory with the force and precision of mathematical demonstration. Former writers on the side of liberty had often observed, that upon the supposition of the inertia of mind, a man, with equal and opposite motives presented at once to his view, would, during their continuance, remain perfectly at rest, like a balance equally loaded in both scales. The observation is

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[1] Inquiry concerning Human Understanding, sect. 8.

[2] The Doctrine of Philosophical Necessity illustrated.

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admitted to be just by all the advocates for necessity; but they contrive to evade its consequences, by denying that in any given case a man can be at once assailed by two equal and opposite motives. Thus, when it is said that a porter, standing with his face due north, must remain in that position at perfect rest, as long as equal motives shall at once be offered to him for travelling eastward and westward, the necessarians admit the force of the argument; but when it is added that a guinea, offered for every mile that he should travel in each of these opposite directions, ought therefore to fix him at rest till one of the offers be withdrawn, they deny that the desire of gaining the guineas is the whole of the motives which operate upon his mind. He may have, say they, some secret reason which we cannot discern for preferring the one direction to the other; and that reason, added to the guinea, will make him go eastward or westward, just as an ounce thrown into either scale of a balance poised by equal weights will make that scale preponderate. Though we think that this solution of the difficulty can satisfy no man who is not already biassed to the necessarian system; and though, even were it to be admitted, it seems to militate against the constant conjunction of motives and actions, unless it can be proved that the porter must travel the road which he has been necessitated to choose with reluctance and a heavy heart; yet as it may admit of endless quibbling upon ambiguous words, the philosophical world is much indebted to Dr Gregory[1] for an argument which, in our opinion, can neither be overturned nor evaded, and which demonstrates that the conjunction of motive and action cannot be constant and inseparable, like that of cause and effect in physics.

The conjunction of motive and action constant.

His reasoning is to this purpose: Suppose a porter to be offered a guinea for every mile that he shall travel directly eastward. If there be no physical cause or moral motive to keep him at rest, or to induce him to move in another direction, there cannot be a doubt, upon either hypothesis, but he will gladly embrace the proposal, and travel in the direction pointed out to him, till he shall have gained as much money as to satisfy his most avaricious desires. The same thing would have happened if a guinea had been offered for every mile that he should travel due south. In these two cases taken separately, the relation between the man's motions and his actions would be strikingly analogous to that between a single impulse and motion in physics. Let us now suppose the two offers to be made at the same instant, and the man to be assured, that if he travel eastward he can have no part of the reward promised for his travelling to the south, and that if he travel southward he can have no part of the reward promised for his travelling to the east. What is he to do in this case? If his mind be inert in volition, and if the two motives operate upon him with the same necessity that causes operate in physics, it is obvious that the man could travel neither towards the east nor towards the south, but in a diagonal direction from north-west to south-east; and this he must do willingly, although perfectly satisfied that he could gain nothing by his journey. As this inference is contrary to fact and universal experience, the doctor very justly concludes that the premises from which it is deduced by mathematical reasoning must also be false and absurd; or, in other words, that the relation between motive and action cannot be that of constant conjunction, like the relation between cause and effect in physics.

He uses many arguments of the same kind, and equally convincing, to prove the absurdity of supposing the inertness of mind, and only an occasional conjunction of motives and actions; but we forbear to quote them, both because we wish his book to be read, and because we think the single argument which we have borrowed from him sufficient to demolish the theory of Priestley and Hume, which rests wholly upon the hypothesis of the constant conjunction of motive and action.

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But is it then not really true, that the external action is determined by the will, the will by desire, and desire by what is agreeable or disagreeable? That the external action is universally determined by the will, is certainly true; but that the will is necessitated and universally determined by the desire, is as certainly false. If Potiphar's wife was handsome, and made her proposals to Joseph with any degree of female address, and if his constitution was like that of other young men, there cannot be a doubt but that he felt a desire to do what she requested of him; yet we know that he willed to do otherwise, and, in direct opposition to his desire, fled from the room. Perhaps it may be said, that his volition to flee was the effect of a contrary and stronger desire not to sin against God; but this is confounding the reader, by calling two energies of mind, between which there is little or no similarity, by the same name. He perceived, or knew, that to comply with his mistress's request would be to sin against God; he knew that he ought not to sin against God, and therefore he chose or determined himself not to do it. We can easily conceive how the presence, attitudes, and address, of the lady might be agreeable to him, and excite desire. There may very possibly be more than one of our readers who, during the course of their lives, have experienced something of the same kind; but could abstract truth be in the same way agreeable, so as to excite in his mind a desire of virtue sufficient to annihilate or banish the desire of the woman? As well may it be said that one sensation can annihilate another, that the beautiful colours of the rainbow can remove the sensation of stench from the mind of him who is plunged into the midst of a dunghill, or that the smell of a rose can make a man insensible to the pain of a stroke inflicted by a bludgeon. In fact, sensual desire, and the perception of duty, are things so totally different, that to consider them as operating against each other, like different weights in the opposite scales of a balance, is as absurd as to suppose that sound can operate against colour, or colour against smell. A man may prefer sound to colour, or colour to smell, and act accordingly; but the determination must be wholly his own, unless these two sensations be themselves either agents or physical causes of the same kind, like the weights in the opposite scales of the balance.

Men do not always determine themselves by the strongest motive.

The advocates for liberty do not pretend, that in matters of importance a man ever acts without some motive or reason for his conduct. All that they insist upon is, that between two or more motives of different kinds he has a liberty of choice, and that he does not always determine himself by that which he knows to be the greatest. Without such freedom, they think men might be often brought into situations where they could not act at all, and where inaction would at the same time be in the highest degree absurd. Thus, were two bags of gold, containing each a thousand or ten thousand guineas, to be placed on the same table, before a man whose family is perishing for want, and were the man to be told that he might take either of them, but not both, is it conceivable that he would be held in perpetual suspense between the two? No; he would instantly and with alacrity take up one of them, without feeling the least regret for the want of the other. This action would, indeed, be the consequence of a very powerful motive, the desire to obtain honestly that wealth of which he and his family stood so much in need. That motive, however, being general, would draw him equally to both

[1] Essay on the Relation between Motive and Action.

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bags; and it remains with the necessarians to say by what else than a self-determining power he could take either the one or the other. When it is affirmed, that such self-determination would be an effect without a cause, the advocates of liberty cannot help thinking that their antagonists are guilty of advancing as an argument a *petitio principii*; for the affirmation is true only if the mind in volition be inert, and the *inertia* of the mind is the sole question at issue. If the mind be not inert, it is plain, that in consequence of a man's self-determination, no effect would be produced without a sufficient cause. At any rate, motives cannot be causes. In the proper sense of the word, a cause is that which produces an effect; but the production of an effect requires active power; and power being a quality, must be the quality of some being by whom it may be exerted. Power may be dormant, and therefore power without will produces no effect. Are motives, then, real beings endowed with power and will? No; they are only views of things or mental conceptions, which in the strictest sense of the word are passive; and between two motives the mind determines itself, without receiving an impulse from either.

Nor is it only between motives of equal force that men have the power of determining themselves. Whoever believes in a future state of rewards and punishments, and yet acts in a manner which he knows to be offensive to Him who is to be the future and final judge, unquestionably prefers to the strongest of all motives, another which even to himself appears to have comparatively but very little strength. Whether there be men who occasionally act in this manner, is a question which can be decided only by an appeal to every one's consciousness. That there are, we can have no doubt; for we never met with a single individual, not biassed by system, who was not ready to acknowledge, that during the course of his life he had done many things, which at the time of action he clearly perceived to be contrary to his true interest. Without a self-determining power in his mind, this could never be the case. Did motives operate with the necessity of physical causes, it is obvious that in every possible situation the strongest must constantly prevail; and that he who in certain circumstances had in time past done any particular thing, would on a return of the same circumstances do the very same thing in every time future. Dr Priestley, indeed, wishes to persuade his readers that this is actually the case. "In every determination of the mind," says he, "or in cases where volition and choice are concerned, all the previous circumstances to be considered are the state of mind (including every thing belonging to the will itself), and the various views of things presented to it;" and he affirms, that "whenever the same precise circumstances occur twice, the very same determination or choice will certainly be made the second time that was made the first." This is an assertion of which no man can controvert the truth, for it is an identical proposition. If in the circumstances previous to the determination of the mind, every thing belonging to the will itself must be included, it is self-evident, that he who in any given circumstances has acted a particular part, will, on a return of these circumstances, act the same part a second time; for this is only saying, that he who on two different occasions shall exert volitions of the same tendency, will not on these occasions exert volitions of which the tendencies are different. But the question to be decided is, whether a man, in the same general state of mind, possessed of the same degree of health, and conscious of the same appetites, must, in external circumstances perfectly alike, necessarily exert at all times the same volitions. That the human mind is under no such necessity, we think every man's consciousness and experience may abundantly satisfy him; for there are, perhaps, but very few who have not at one time resisted temptations, to which at another they have chosen to yield.

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That there is a relation between motives and actions, must be confessed; but that relation is neither necessity nor constant conjunction. If it were, all actions would be perfectly rational; and folly, as well as merit and demerit, would be banished from the conduct of men. What is the particular nature of that relation which subsists between the voluntary actions of men, and the motives from which they proceed, can be known to every individual only by an attentive and unbiassed reflection on the operations of his own mind. Without this reflection, no man can be made to understand it by the reasonings of philosophers, and with it no man can need the aid of those reasonings. That a self-determining power, such as that for which we plead, contributes to the sum of human happiness, has been shown by Archbishop King and his ingenious translator, who have proved, with the force of demonstration, that the mind can take pleasure in the object of its choice, although that object be in itself neither agreeable nor disagreeable to our natural appetites; and that if it could not, it would be in vain in such a world as ours to hope for any portion of felicity. Into that detail our limits will not permit us to enter; but to the reader who wishes for further information, we beg leave to recommend the last edition of King's Origin of Evil, by Dr Law, late bishop of Carlisle; without, however, vouching for the truth of all the opinions advanced by either of those learned writers.

If they did, folly, as well as merit and demerit, would be banished from the world.

Before we conclude this chapter, it may be proper to observe here, that it is only in volition that we are conscious of any original active power in ourselves, and that without such consciousness we could never have acquired the notion of active power. In our desires and appetites, we neither are active nor suppose ourselves active. Lord Kames, and most necessarians, confound desire with volition; but that they are perfectly distinct is plain from this circumstance, that we daily desire many things which we know to be wholly out of our own power,[1] whereas no man ever willed what he did not believe to be in his own power. We all desire or wish that our children may be virtuous, wise, and happy; and although we are conscious that it is not in our power to make them so, we cannot banish the desire from our breasts. But madmen only have ever willed virtue, and wisdom, and happiness, to any person; and if there ever was a man so extravagantly mad as to exert such a volition as this, he must at the time have fancied himself a divinity, and therefore believed that the object of his volition depended upon himself. When the astronomer, whose character is so admirably drawn by our great master of moral wisdom,[2] fancied himself the regulator of the weather and the distributor of the seasons, he might will either rain or sunshine as he thought proper, because he considered the object of his volition as depending upon a power imparted to him from heaven; but though he might desire, he could not will, the rising or the falling of winds, for these he confessed were not subjected to his authority. In a word, without freedom in volition, power is inconceivable; and therefore it is as certain that we are free agents, as that we have any notion of active powers.

CHAP. VI.—OF THE BEING AND ATTRIBUTES OF GOD.

It has been already observed, that as of bodies there are various kinds, endowed with various properties; so the pro-

[1] Reid's Essays on the Active Powers of Man.

[2] Rasselas, Prince of Abyssinia.

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bability is, that of minds endowed with different powers, or different degrees of power, the variety may be as great, or perhaps greater. The existence and powers of our own minds are made known to us by consciousness and reflection; and, from our dependent state, and the mutability of the objects around us, we are necessarily led to infer the existence of another mind, which is independent, unchangeable, eternal, and the cause of all things which have a beginning of existence. Between that mind and our own we can hardly avoid believing that there are many orders of "thrones, dominations, princedoms, virtues, powers;" but as we possess no intuitive knowledge of such intermediate beings, and cannot, from any thing which we perceive, discern the necessity of their existence, they are not properly the object of science. The existence, however, and many of the attributes, of the One First Cause, are capable of the strictest demonstration; "for the invisible things of him from the creation of the world are clearly seen, being understood by the things which are made."

Of this great truth, the most important by far which can occupy the mind of man, many demonstrations have been given both by divines and by philosophers. We shall lay before our readers such an one as to us appears perfectly conclusive, being founded on the intuitive knowledge which we have of our own existence, and therefore independent of all theories about the nature and reality of the material world.

Some one independent Being has existed from eternity.

Every man, whether he adopt the common theory or that of Berkeley respecting matter, is conscious that he himself exists, and must therefore grant that something now exists. But if any thing exists now,[1] then must something have existed always; otherwise that thing which now exists must either have been created by nothing, that is, have been caused by no cause, or else it must have created itself, acting before it existed. Both these suppositions are so palpably absurd, that no atheist has avowed them, either amongst the ancients or the moderns. We must therefore admit, either that there is some one independent being, which now exists, and always has existed; or that the things which we know to exist at present (every man's self, for instance) were produced by something which had its existence from something else, which also depended upon some other cause, and so on in an infinite series of caused or successive beings. But this last supposition, though it has been often made, is as grossly absurd as either of the two former. For of this infinite series, either some one part has not been successive to any other, or else all the several parts of it have been successive. If some one part of it was not successive, then it had a first part, which destroys the supposition of its infinity.[2] If all the several parts of it have been successive, then have they all once been future; but if they have all been future, a time may be conceived when none of them had existence; and if so, then it follows, either that all the parts, and consequently the whole of this infinite series, must have arisen from nothing, which is absurd; or else that there must be something in the whole besides what is contained in all the parts, which is also absurd.

As the possibility or impossibility of an infinite series of dependent beings is the main question at issue between the atheists and us, we shall state the preceding reasoning in a manner somewhat different. For this purpose, let us suppose some one to affirm that the course of generation has had no beginning, and consequently that the number of successive births has been infinite. We would ask such a person, whether, before the birth of Abraham, for example,[3] there had passed an infinite series of generations or not? If not, the course of generation must have had a beginning, which is the conclusion for which we contend. But if the series past was infinite, then at the birth of Joseph, the great-grandson of Abraham, it is evident that more generations were past, and that the number then was greater than that which was supposed to be infinite; so that upon this supposition we have a number that is both infinite and not infinite, which is a manifest contradiction. Should it be said that the number of generations was infinite, as well at the birth of Abraham as at the birth of Joseph; it will then follow, that one infinite may be greater than another of the very same kind, and consequently that an infinite may be bounded, that is, be finite. But should it be alleged, that the number of births at Abraham's was finite, and became infinite when it reached to Joseph's, it will then follow that one finite number added to another may make an infinite number, which is directly contrary to every possible notion of infinity. We might argue in the same manner against an infinite series of every kind, the very supposition of which involves the most palpable contradictions. (See the Chapter on Infinity and Eternity.)

Of the Being and Attributes of God.

His duration is not commensurate with succession.

From the impossibility of an infinite series it necessarily follows, that there exists, and must have existed from eternity, some one independent being, whose duration cannot be commensurate with succession, and to whom the relation of time is not applicable. Here will some atheists presently imagine, that by the same mode of reasoning they may disprove the existence of God; for do not they who thus destroy the eternity of the world, destroy at the same time the eternity of the Creator? If time itself be not eternal, how can the Deity or any thing else be so?

In urging these questions, it must be taken for granted that time is essential to all existence, and that God cannot be eternal otherwise then by a successive flux of infinite time. But it has been already shown, in treating of time, that successive duration is not essential to existence; that we can even conceive existence without succession; and it may here be added, that if we suppose a perfect being alone in nature, we shall find it impossible to imagine any succession of ideas, any flux of moments, or any alteration or increase whatever in his knowledge and essence. Such duration as we are acquainted with can have no relation to an immutable Being, whilst supposed to exist alone; but as soon as he determined to exercise his several attributes in the production of something distinct from himself, then, and not till then, have we reason to think that time, succession, and increase, began. These atheistical questions, therefore, instead of containing an objection to the existence of a Deity, afford a plain demonstration of it; for since it is more evident that something now exists, than that something must have existed from eternity, and since it has been shown, that neither the world in its present state, nor time, nor indeed any thing capable of change or succession, can possibly be eternal, it follows that there must necessarily be some Being who, in the order of nature, is before time, and who, in the stability and immutable perfection of his own intelligence, comprehends at once his yesterday, to-day, and for ever. "The atheists," says the excellent Cudworth,[4] "can here only smile, or make wry faces, and show their little wit in quibbling upon *nunc-stans*, or a standing now of eternity; as if that standing eternity of the Deity (which with so much reason hath been contended for by the ancient genuine theists) were nothing but a pitiful small moment of time standing still, and as if the duration of all beings whatsoever must needs

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[1] See Notes to King's Origin of Evil.

[2] Των ἀπειρων ουκ ἐστιν οὐδεν πρωτον. (Arist. *Phys.* lib. viii. cap. v. sect. 4.)

[3] See an Essay towards an Eviction of the Attributes of God, by Seth Ward. Printed at Oxford, 1655.

[4] Intellectual System, book i. chap. 5.

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be like our own; whereas the duration of every thing must of necessity be agreeable to its nature; and therefore, as that whose imperfect nature is ever flowing like a river, and consists in continual motion and changes one after another, must needs have accordingly a successive and flowing duration sliding perpetually from present into past, and always hasting on towards the future, expecting something of itself which is not yet in being; so must that whose perfect nature is essentially immutable have permanent and unchanging duration, never losing any thing of itself once present, nor yet running forward to meet something of itself which is not yet in being."

He is self-existent, and cannot cease to be.

From the eternity of the Supreme Being we necessarily infer his independence or self-existence; for that which never had a beginning of existence cannot possibly have any cause of that existence, or in any manner depend upon any other being, but must exist of itself, or be self-existent. Eternity *ad partem post*, or necessary existence, or the impossibility of ever ceasing to be, follows from independence; for to the nature of that which exists without any cause, existence must be essential. But a being whose existence is of itself, and essential to its nature, cannot be indifferent to existence or non-existence, but must exist necessarily. And here it may be proper to observe, that the word *necessity*, when applied to existence, may be taken in two acceptations very different from each other;[1] either as it arises from the relation which the existence of that being, of which it is affirmed, has to the existence of other things; or from the relation which the actual existence of that thing has to the manner of its own existence.

What is meant by necessary existence.

In the former sense, when necessity of existence has relation to the existence of other things, it denotes that the supposition of the non-existence of that thing of which necessity is affirmed, implies the non-existence of things which we know to exist. Thus, some independent being does necessarily exist; because, to suppose no independent being, implies that there are no dependent beings, the contrary of which we know to be true. In the second sense, when the necessity of existence arises from the relation which the actual existence of any thing has to the manner of its own existence, necessity means, that the thing of which it is affirmed exists after such a manner as that it never could in time past have been non-existent, nor can in time future cease to be. Thus, every independent being, as it exists without a cause, is necessarily existing, because existence is essential to such a being; so that it never could begin to exist, and never can cease to be. For to suppose a being to begin to exist, or to lose its existence, is to suppose a change from nonentity to entity, or *vice versa;* and to suppose such a change is to suppose a cause upon which that being depends. Every being, therefore, which is independent, that is, which had no cause of its existence, must exist necessarily, and cannot possibly have begun to exist in time past, or cease to be in time future.

Only one necessarily existent being.

These two kinds of necessity, as applied to existence, though they have been often confounded, are in themselves perfectly distinct; for though a being cannot be necessarily existent in the former sense without being so in the latter also, yet may it be necessarily existent in the latter sense without being so in the former. For any thing that we know to the contrary, there may be two or more beings existing necessarily in the latter sense of the word necessity, that is, with regard to independence and the manner of their own existence; but in the former sense of the word, or in relation to this system, there can be but one necessarily existent being; for it is obvious that no more are necessary to account for the production of the dependent beings which we know to exist. To suppose the non-existence of all independent beings, implies the non-existence of all dependent beings, ourselves, and every thing else; but to suppose the non-existence of all independent beings except one, involves in the supposition no such absurdity.

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Thus the phenomena of nature lead us, by the strictest reasoning, to one First Cause, which is sufficient for their production; and therefore none but one First Cause can in this sense of the word be necessary. And though several more independent beings might possibly exist, yet they would be no gods to us; they would have no relation to us demonstrable by reason, nor we any thing to do with them. For if the supposition of their existence were not requisite to the production of this system, which it obviously would not be, we could not perceive any necessity for it at all; we could never discover it by our own faculties, and therefore it could be nothing to us. And although two or three such beings should exist, and act in the formation and government of their respective systems, or agree in one; yet, till their existence and operations were made known to us, and a natural relation discovered, nothing could be due from us to them. They would have no religious or moral relations to us; and we should have no reason to call more than one of them our creator, preserver, and governor, which is the proper sense of the word God.

Impossible to demonstrate that there can be but one self-existent Being.

To show in this manner that there is only one eternal self-existent Being, which bears the relation of God to us, seems to be going as far as is necessary, or as natural light will lead us. Those who endeavour to demonstrate that there cannot possibly be more than one self-existent Being, either reason in a circle, or proceed upon principles which their antagonists cannot be compelled to admit. When they deduce the divine unity from independence or omnipotence, they evidently presuppose it in their definition of these attributes; and when they infer it from the nature of space and duration, which they consider as modes of the self-existent Being, they take it for granted that space and duration have a real existence, independently of us and our thoughts; and that the one is infinite and the other eternal, contrary to what has been already proved, we think, with the force of demonstration. The celebrated Dr Clarke made much use of space and duration in his attempt to demonstrate that there can be but one self-existent Being; but he argues for the same thing from the nature of necessity as applied to existence.

Dr Clarke's first demonstration of the unity inconclusive.

"Necessity," says he,[2] "absolute in itself, is simple and uniform and universal, without any possible difference, difformity, or variety, whatsoever; and all variety or difference of existence must needs arise from some external cause, and be dependent upon it, and proportionable to the efficiency of that cause, whatsoever it be. Absolute necessity, in which there can be no variation in any kind or degree, cannot be the ground of existence of a number of beings, however similar and agreeing; because, without any other difference, even number is itself a manifest difformity or inequality (if I may so speak) of efficiency or causality."

Such is this great man's first argument from necessity, to prove that there cannot be more than one self-existent Being. But what is this necessity which proves so much? It is the ground of existence, he says, of that which exists of itself; and if so, it must, in the order of nature, and in that of our conceptions, be antecedent to that being of whose existence it is the ground. Concerning such a principle, there are but three suppositions which can possibly be made; and all of them may be shown to be absurd and

[1] Notes to King on Evil; and Law's Inquiry into the Ideas of Space, &c.
[2] Demonstration of the Being and Attributes of God, Prop. vii.

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contradictory. We may suppose either the substance itself, some property of that substance, or something extrinsic to both, to be this antecedent ground of existence prior in the order of nature to the first cause.

One would think, from the turn of the argument which here represents this antecedent necessity as efficient and causal, that it were considered as something extrinsic to the first cause.[1] Indeed, if the words have any meaning in them at all, or any force of argument, they must be so understood, just as we understand them of any external cause producing its effect. But as an extrinsic principle is absurd in itself, and is besides rejected by Dr Clarke, who says expressly, that "of the thing which derives not its being from any other thing, this necessity or ground of existence must be in the thing itself," we need not say a word more of the last of these suppositions.

Let us then consider the first; let us take the substance itself, and try whether it can be conceived as prior or antecedent to itself in our conceptions, or in the order of nature. Surely we need not observe that nothing can be more absurd or contradictory than such a supposition. Dr Clarke himself repeatedly affirms, and it would be strange indeed if he did not affirm, that no being, no thing whatever, can be conceived as in any respect prior to the first cause.

The only remaining supposition is, that some attribute or property of the self-existent Being may be conceived as in the order of nature antecedent to that being. But this, if possible, is more absurd than either of the two preceding suppositions. An attribute is attributed to its subject as its ground or support, and not the subject to its attribute. A property, in the very notion of it, is proper to the substance to which it belongs, and subsequent to it both in our conceptions and in the order of nature. An antecedent attribute, or antecedent property, is a solecism as great, and a contradiction as flat, as an antecedent subsequent or subsequent antecedent, understood in the same sense and in the same syllogism. Every property or attribute, as such, presupposes its subject, and cannot otherwise be understood. This is a truth so obvious and so forcible, that it sometimes extorts the assent even of those who upon other occasions labour to obscure it. It is confessed by Dr Clarke,[2] that "the scholastic way of proving the existence of the self-existent Being from the absolute perfection of his nature, is ὑστερον πρoτερον. For all or any perfections," says he, "presupposes existence, which is a *petitio principii*." If therefore properties, modes, or attributes in God, be considered as perfections (and it is impossible to consider them as any thing else), then, by this confession of the great author himself, they must all or any of them presuppose existence. It is indeed immediately added in the same place, "that bare necessity of existence does not presuppose, but infer existence;" which is true only if such necessity be supposed to be a principle extrinsic, the absurdity of which supposition has been already shown, and is indeed universally confessed. If it be a mode or a property, it must presuppose the existence of its subject, as certainly and as evidently as it is a mode or a property. It might perhaps *a posteriori* infer the existence of its subject, as effects may infer a cause; but that it should in the other way *a priori*, is altogether as impossible as that a triangle should be a square, or a globe a parallelogram.

Doubtful, as it would seem, of the force of his first argument, which even those who pretend to be convinced by it acknowledge to be obscure, the doctor gives a second, which we must confess appears to us to be still more obscure, and if possible less conclusive. "To suppose two or more distinct beings existing of themselves necessarily and independent of each other, implies," he says, "this contradiction, that each of them being independent from the other, they may either of them be supposed to exist alone; so that it will be no contradiction to suppose the other not to exist; and consequently neither of them will be necessarily existing. Whatsoever therefore exists necessarily is the one simple essence of the self-existent Being; and whatsoever differs from that is not necessarily existing, because in absolute necessity there can be no difference or diversity of existence.

Of the Being and Attributes of God. Second demonstration of the same author equally inconclusive.

"Necessity is used here in two different senses,[3] both as absolute and relative. In the former, neither of the two beings can exist without the other, that is, without our supposing the other to exist also, since that is equally necessary. In the latter, either of them may exist alone, *i. e.* as without the help of the other, or without the supposition of the other as requisite to its own existence. The consequence, therefore, that either of them may exist alone, and so neither of them is necessary, is a mere equivocation on necessity, using it both in an absolute and relative sense at the same time." But as this is a question of the highest importance, and as the author was a man of great worth, we shall consider his argument upon the supposition that the word *necessity* has from the beginning to the end of it the same invariable meaning.

It has already been observed, that there are only two senses in which the word *necessity* can be applied to the existence of any being; and whether it be here used in the one or the other of these senses, the reasoning, if resolved into a syllogism, will appear to be inconclusive. If the word be taken in that sense of necessity which arises from the relation that dependent beings which we know to exist bear to some one independent Being, the argument will stand thus:—From a known effect no more causes can be necessarily inferred than what are sufficient to account for that effect; but one self-existent and independent Being is sufficient to account for all the phenomena of nature; therefore, from the phenomena, &c. no more than one such being can be necessarily inferred to exist.

But although no more than one independent being can in this sense of the word necessarily exist, it by no means follows from this syllogism, that two or more such beings may not possibly exist. It is, indeed, a plain contradiction to say, that two or more self-existent beings are in this sense necessary; but surely there is no contradiction in saying that two or twenty of such beings are possible. We could not, therefore, by this argument convict a person of absurdity, who should affirm that two or more independent beings actually exist. We might indeed deny the existence of them all but one, because one is sufficient to account for those phenomena, from which alone we know that any independent being exists; but because one of them might be supposed to exist alone, so that it would be no contradiction to suppose the other not to exist; we know not how the doctor came to affirm, in direct opposition to his own demonstration, that not one of them would be necessarily existing.

Necessity, as applied to existence, in the other sense of the word, arises, as we have seen, from the relation which the actual existence of the being of which it may be affirmed, has to the manner of that being's existence. It is the same necessity, we are told,[4] with that which is the cause of the unalterable proportion between two and four; and it is considered as the formal cause or ground of the existence of an independent being. Were it not for the

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[1] Dissertation on the Argument *a priori*, added to Law's Inquiry into the Ideas of Space, Time, Immensity, &c.
[2] Answer to the Sixth Letter.
[3] Law's Inquiry into the Ideas of Space, &c. chap. vi.
[4] Answer to the Sixth Letter from a Gentleman in Gloucestershire.

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strange expressions *formal cause* and *ground of existence*, we should have no objection to this account of that necessity by which a being independent undoubtedly exists; but this kind of necessity is a principle which will not support the superstructure which the learned author labours to raise upon it. The same necessity which is the cause of the unalterable proportion between two and four, is likewise the cause of the unalterable proportion between three and six, between four and eight, and between five and ten, &c. But if it can be the cause of so many different proportions of the same kind, why may it not be the formal cause or ground of existence to as many independent beings of the same kind, as well as to one? The following syllogism we apprehend to be legitimate both in mode and figure, and its conclusion is directly contrary to the proposition which the doctor deduces from the same notion of necessity.

If necessity, considered as a formal cause or ground of existence, be in one instance of its causality the formal cause or ground of existence to many things of the same kind, it may likewise, in every other instance of its causality, be the formal cause or ground of existence to many things of the same kind. But such necessity, in that instance of its causality where it is the formal cause or ground of existence to the unalterable proportion between two and four, is the formal cause or ground of existence to many proportions of the same kind. Therefore, the same necessity in that other instance of its causality where it is said to be the formal cause or ground of existence to one independent being, may undoubtedly be the formal cause or ground of existence to many independent beings of the same kind.

Necessity a dangerous principle.

Thus it appears that necessity, in any sense in which it can be properly affirmed of existence, cannot be the foundation of any argument to prove the impossibility of more than one self-existent being. It is indeed a principle from which we apprehend that no positive conclusion whatsoever can be deduced by reasoning *a priori*. That necessity of existence may be predicated of a being which is independent and uncreated, is self-evident; because to the nature of such a being existence is essential. But whilst that nature itself remains wholly incomprehensible by us, it is impossible that we should discover, by our own unassisted reason, whether it can be the nature of only one, or of more than one, independent being. To argue from necessity, as if it were the cause or ground of existence to such a being, is certainly absurd, if it be not impious; for if that to which existence is essential, does not exist without any cause efficient or formal, we shall be obliged to inquire after a cause or ground of this cause, and thus be involved in all the absurdities and contradictions of an infinite series. We have insisted the longer on this point, because necessity, as the foundation of the argument *a priori*, has sometimes been employed to very bad purposes. Attempts have indeed been made, from the notion of necessary existence, to prove that the Supreme Being cannot be a free agent, and to set the first principles of the religion of nature at variance with those which are revealed in the Scriptures.

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The unity of God highly probable.

But although we are firmly persuaded that the divine unity cannot be demonstrated *a priori*, we are far from thinking it incapable of any proof. On the contrary, the common arguments *a posteriori*, drawn from the order and harmony of the world, have always satisfied us, and in our opinion must satisfy every person capable of proportioning his assent to evidence, that the Creator and Preserver of such a system has but one will and one intelligence, and therefore is himself but one being. But proof is one thing, and demonstration is, in the proper sense of the word, another.[1] And if we cannot arrive at absolute certainty concerning this important truth by the light of nature, we ought to be the more thankful for that revelation, which has put the unity of God beyond dispute to all who believe the holy Scriptures.

God omnipotent.

The being which is self-existent and independent must be also omnipotent. That such a being has active power in some degree, is shown at the same time and by the same medium that we prove his existence; and since he depends upon no cause for his existence or his power, he cannot depend upon any for the exertion of that power, and consequently no limits can be applied to it. Limitation is an effect of some superior cause, which in the present instance there cannot be; consequently, to suppose limits where there can be no limiter, is to suppose an effect without a cause. For a being to be limited or deficient in any respect,[2] is to be dependent in that respect on some other being which gave it just so much and no more; consequently that being which in no respect depends upon any other is in no respect limited or deficient. In all beings capable of increase or diminution, and consequently incapable of perfection or absolute infinity, limitation or defect is indeed a necessary consequence of existence, and is only a negation of that perfection which is wholly incompatible with their nature; and therefore in these beings it requires no further cause. But in a being naturally capable of perfection or absolute infinity, all imperfection or finiteness, as it cannot flow from the nature of that being, appears to require some ground or reason; which reason, as it is foreign to the being itself, must be the effect of some other external cause, and consequently cannot have place in the first cause. That the self-existent being is capable of perfection or absolute infinity must be granted, because he is manifestly the subject of one infinite or perfect attribute, namely eternity, or absolute invariable existence. In this respect his existence has been shown to be perfect, and therefore it may be perfect in every other respect also. Now that which is the subject of one finite attribute or perfection, must have all its attributes infinitely or in perfection; since to have any perfections in a finite limited manner, when the subject and these perfections are both capable of strict infinity, would be the absurdity before mentioned of positive limitation without a cause. To suppose this eternal and independent being limited in or by its own nature, is to suppose some antecedent nature or limiting quality superior to that being, to the existence of which no thing, no quality, is in any respect antecedent or superior. And to suppose that there is no such thing as active power in a

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[1] John Gerhard and John Vossius both cite Gabriel Biel as acknowledging the unity of God to be incapable of rigid demonstration; and with the sentiments of that schoolman those two learned divines profess that their own agree.

Sed Biel (1 Sant. Dist. 2 Q. 10, art. 3) statuit "quod tantum unum esse Deum, sit creditum et non demonstratum ratione naturali nobis in via possibili." Id nos ita interpretamur; etiamsi ex naturæ libro rationes non contemnendæ pro unitate divinæ essentiæ asserenda erui possint, eas tamen ad fidei πληροφοριαν cordibus nostris ingenerandum, non satis efficaces esse. Ergo mens prius confirmanda est ex verbo Dei, et illustribus testimoniis in quibus se Deus generi humano patefecit: Postea utiliter potest addi consideratio philosophicarum demonstrationum. (Gerhard. *Loc. Comm.* tom. i. p. 106.)

Dissentit Gabriel Biel, qui ante annos hosce 140 Tubingensi Gymnasio præfuit. Is censet probabiles magis rationes esse quam evidentes et certas. Verum esto sane, ut solæ non sint ἀποδειχτικαι: At magnum iis pondus addit traditio vetus; tum autem quod argumenta isthæc, si non prorsus ἀποδειχτικα, saltem usque adeo probabilia sint, ut της πολυθειας patroni nihil ullius momenti adferre valeant; cur plusquam unum statuere deum potius conveniat. (Voss. *De Idolatria*, lib. i. c. ii.)

[2] Notes to King on Evil.

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being which is evidently the fountain of all power, is the grossest of all absurdities. The same method of reasoning will prove that knowledge and every other perfection is infinite in the Deity, when once we have proved that perfection to belong to him at all; at least it will show, that to suppose it limited is unreasonable, since we can find no manner of ground for limitation in any respect; and this is as far as we require to go, or perhaps as natural reason will lead us.

Omnipotence can do every thing which does not imply a contradiction.

Of the omnipotence of the Supreme Being, some philosophers, as well theists as atheists, have talked very absurdly. Hobbes,[1] with a view to make this attribute appear impossible and ridiculous, affirms "that God by his omnipotence or infinite power could turn a tree into a syllogism." And Descartes,[2] though certainly no atheist, childishly asserts, that all things whatever, even abstract truth and falsehood, do so depend upon the arbitrary will and power of God, as that if he had pleased, "twice two should not have been four, nor the three angles of a plane triangle equal to two right ones." But the true motion of Omnipotence, so far from implying a power to turn a tree into a syllogism, or to make twice two not equal to four, implies only that the Being possessed of it can actually perform whatever can be conceived by the most perfect understanding, conception in this case being the measure of possibility. Now every thing may be conceived by a mind sufficiently enlarged, which does not involve in it a direct contradiction; but what we clearly discern to imply a contradiction, such as that a thing may be and not be at the same instant, cannot be conceived by any intellect, or made to exist by any power. And thus has this attribute of the Deity been always stated, not only by the wiser Christians, but also by most of the ancient philosophers, who expressly admit that "nothing is exempted from the divine power, but only to make that which has been done to be undone."

Creation possible to Omnipotence.

And here it may be asked, whether creation, in the proper sense of the word, be within the compass of infinite power. All the ancient philosophers, who were unenlightened by the rays of divine revelation, held that it is not;[3] grounding their opinion on the well-known maxim, *Ex nihilo nihil fit.* But this maxim will support no such conclusion. The ancients, or at least the Peripatetic school, with the metaphysics of which we are best acquainted, considered four kinds of causes, the efficient, the material, the formal, and the final; and though they extended the maxim to the first two, if not to all these causes, it is a self-evident truth only when applied to the efficient cause. Without the actual exertion of power, it is indeed most certain that nothing could have been brought into existence; but it is so far from being clear that pre-existent matter, or, as Aristotle chose to express himself, a material cause, must be supposed for infinite power to operate upon, that we think every man may discover complete evidence of the contrary in himself. That sensation, intelligence, consciousness, and volition, are not the result of any modifications of figure and motion, is a truth as evident as that consciousness is not swift, nor volition square. If, then, these be the powers or properties of a being distinct from matter, which we think capable of the most complete proof, every man who does not believe that his mind has existed and been conscious from eternity, must be convinced that the power of creation has been exerted in himself. If it be denied that there is any immaterial substance in man, still it must be confessed, that, as matter is not essentially conscious, and cannot be made so by any particular organization, there is some real thing or entity, call it what you please, which has either existed and been conscious from eternity, or which has been in time brought from nonentity into existence by an exertion of infinite power.

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Objection answered.

To this perhaps some one may object, that upon our own supposition of the inability of the human mind to exert its faculties except in union with some material and organized system, the mind of every man may have existed from eternity without being conscious of its own existence; and that, therefore, we have in ourselves no evidence of creation, but only of the union of two self-existent substances, which, in their prior state, had been distinct and separate from each other. But such an objection as this which we have now stated can arise from nothing but misapprehension of our hypothesis, and of the reasons by which it has been supported. We suppose, that to the exertion of the human faculties, a body of some kind or other may be necessary as an instrument, not merely from what we observe of the dependence of perception and memory upon the state of the brain, but because we cannot conceive a Creator of infinite wisdom and goodness to immerse in systems of matter, minds to which he knows that such systems must always be useless, and often hurtful. We believe, therefore, that our souls and bodies were created and formed for each other; but as our present adversaries admit not of a Creator, we must ask them, How their self-existent souls have been disposed of from eternity, and by what power they have all in due succession been united each to its proper body? As before the union they were not conscious, they could not unite themselves; and to suppose them united by some superior intelligence, is to suppose them in some respects dependent upon that intelligence, which seems not to accord with their self-existence. Whatever is self-existent and eternal must be independent; and if possessed of any power, it cannot be conceived to have that power limited. We repeat, therefore, that every man has in himself sufficient evidence that creation is possible; for if infinite power can create an immaterial and percipient being, it may surely be supposed capable of creating dead and unintelligent matter.

The creation of the material system probable.

But the creation of the material system may be shown to be in the highest degree probable by other arguments. The same reasoning which proves the impossibility of an infinite series and of eternal time, proves that the universe cannot have existed from eternity in its present state. But if it has not existed from eternity in its present state, it belongs to the opponents of creation to say what was its former state. We talk indeed of chaos; but such language, when a Creator is not admitted, is most unphilosophical trifling. It appears from the most accurate inquiries which have been made into the substance and essence of body,[4] that the atoms of which each mass is composed are held together by a foreign force. If by chaos be meant matter, when this force is supposed to be removed, we must beg leave to say, that of such a substance we have neither idea nor notion, and cannot distinguish it from nonentity. The original atoms of matter we believe indeed to require no other agency to keep each entire than that fiat by which it was created; but still, as those atoms are conceived to be solid and extended, they must be capable of division by infinite power; and if that fiat or influence which makes them solid and extended were removed, they would lose solidity and extension, and of course become nothing. So far is it, therefore, from being true, that the creation of matter appears to be impossible, that we are compelled by every thing which we know of it to believe that matter cannot possibly be self-existent.

"Because it is undeniably certain, concerning ourselves,"

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[1] *Leviathan*, chap. iii. [2] *Responsio ad Objectionem Sextam*, sect. 6.
[3] See Mosheim's Dissertation on this Subject, in his Edition of Cudworth's Intellectual System.
[4] Baxter's Inquiry into the Nature of the Human Soul.

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Observations of Cudworth.

says Cudworth,[1] "and all imperfect beings, that none of these can create any new substance, men are apt to measure all things by their own scantling, and to suppose it universally impossible for any power whatever thus to create. But since it is certain, that imperfect beings can themselves produce some things out of nothing pre-existing, as new cogitations, new local motion, and new modifications of things corporeal, it is surely reasonable to think that an absolutely perfect being can do something more, that is, create new substances, or give them their whole being. And it may well be thought as easy for God, or an Omnipotent Being, to make a whole world, matter and all, ἐξ οὐκ ὄντων, as it is for us to create a thought or to move a finger, or for the sun to send out rays or a candle light; or, lastly, for an opaque body to produce an image of itself in a glass or water, or to project a shadow; all these imperfect things being but the energies, rays, images, or shadows of the Deity. For a substance to be made out of nothing by God, or a Being infinitely perfect, is not for it to be made out of nothing in the impossible sense, because it comes from Him who is all. Nor can it be said to be impossible for any thing whatever to be made by that which hath not only infinitely greater perfection, but also infinite active power. It is indeed true, that infinite power itself cannot do things in their own nature impossible; and, therefore, those who deny creation, ought to prove, that it is absolutely impossible for a substance, though not for an accident or modification, to be brought from non-existence into being. But nothing is in itself impossible which does not imply contradiction; and though it be a contradiction to be and not to be at the same time, there is surely no contradiction in conceiving an imperfect being, which before was not, afterwards to be." To call in question the possibility of creation, because we have no adequate conception how a thing can be brought into existence, would be in the highest degree absurd; for it may be doubted whether we have adequate conceptions of any thing excepting our own ideas and their various relations.

God a free agent, but unchangeable.

That Being which is self-existent, omnipotent, and omniscient, is not a necessary, but a free agent; for active power implies freedom, and infinite power infinite freedom. What, therefore, has no bounds set to its power, what can have no opposition made to its will, nor restraint laid on its actions, must both will and act freely. If the Supreme Cause were not a being endowed with liberty and choice, but a mere necessary agent, then would it follow, as Dr Clarke well observes,[2] that nothing which is not could possibly have been; and that nothing which is could possibly not have been; and that no mode or circumstance of the existence of any thing could possibly have been in any respect otherwise than it now actually is: all which being evidently most false and absurd, it follows, on the contrary, that the Supreme Cause is not a mere necessary agent, but a Being endued with liberty and choice.

To this reasoning it has been replied,[3] that Dr Clarke "must have known, that all those who contend against the free agency of the Deity, do of course acknowledge, that nothing could have happened, or does happen, or will happen, but what actually has happened, or doth happen, or will happen; and that it is most false and absurd to deny it." It is, therefore, according to the necessarians, absolutely impossible that at present there could exist upon this earth more or fewer persons than are now actually alive; that the earth could move in any other direction than from west to east, or that there could be more or fewer planets in the solar system. Yet it is most certain that there have been fewer persons on the earth than there are now; that there is not a cultivated country in Europe which could not contain more people than now inhabit it; that the comets move in very different directions from that of west to east; and that as, until lately, we conceived there were only six primary planets in the system, it is evidently possible that the system might contain more. Upon the supposition, therefore, that the Supreme Being acts under a physical necessity, the same things are possible and not possible at the same time, which is the grossest of all absurdities. It might have been objected with much more plausibility, that the First Cause cannot possibly be free, because he must needs do always what is best on the whole; but it will be seen by and by, that amongst different created systems, there is no reason for supposing any one absolutely best.

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But although this Being be free, and as such the author of change in other beings, yet he must himself be unchangeable; for all changes have a beginning, and consequently are effects of some prior causes. But there can be nothing prior to the existence of this Being, because he is eternal; neither can there be any cause of his existence, because he is independent; nor consequently any change in it, except we could suppose him to change himself, which is the same absurdity as to produce himself, or to be at the same time both effect and cause.

Omniscience, &c. proved in a different manner.

Omniscience, as well as some of the foregoing attributes of the Supreme Being, may perhaps be more easily deduced in a different manner.[4] We find in ourselves such qualities as thought and intelligence, power and freedom, &c. for which we have the evidence of consciousness as much as for our own existence. Indeed it is only by our consciousness of these that our existence is made known to ourselves. We know likewise that these are perfections, and that to have them is better than to be without them. We find also that they have not been in us from eternity. They must, therefore, have had a beginning, and consequently some cause, for the very same reason that a being which begins to exist in time requires a cause. Now this cause, as it must be superior to its effect, must have those perfections in a superior degree; and if it be the first cause, it must have them in an infinite or unlimited degree, since bounds or limitation without a limiter would, as we have already shown, be an effect without a cause.

It is indeed obvious that the omniscience of the Supreme Being is implied in his very existence. "For all things being not only present to him, but also entirely depending upon him, and having received both their being itself and all their powers and faculties from him, it is manifest that as he knows all things that are, and penetrates every part of their substance with his all-seeing eye, so must he likewise know all possibilities of things, that is, all effects that can be. For, being alone self-existent, and having alone given to all things all the powers and faculties with which they are endued, it is evident that he must of necessity know perfectly what all and each of these powers and faculties, which are derived wholly from himself, can possibly produce. And seeing at one boundless view, or more properly in his own ideas, all the possible compositions and divisions, variations and changes, circumstances and dependencies of things, all their possible relations one to another, and their dispositions or fitnesses to certain and respective ends, he must without possibility of error know exactly what is best and most proper in every one of the numberless possible cases, or methods of disposing things, and understand perfectly how to order and direct the respective means to bring about what he so knows to be in its kind, or upon the whole, the best and fittest in the end. This is

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[1] Intellectual System, book i. chap. v.
[2] Demonstration of the Being and Attributes of God.
[3] Cooper's Tracts.
[4] Notes to King on Evil.

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what is meant by infinite wisdom, or omniscience;"[1] and it has been readily admitted by every man who believed in the existence of a God, as the creator and preserver of all things.

God foreknows the actions of free agents.

Doubts, however, have been entertained by theists, and pious theists, whether omniscience itself can certainly foreknow what are called contingent events, such as the actions of free agents; and some few there are professing even to be Christians, who have boldly pronounced such knowledge to be impossible. That we have no adequate notion how events which are called contingent can be certainly foreknown, must indeed be granted; but we are not, therefore, authorized to say that such knowledge is impossible, unless it can be clearly shown to imply a contradiction. They who suppose that it implies a contradiction, must likewise suppose, that, where there is not a chain of necessary causes, there can be no certainty of any future event; but this is evidently a mistake. "For let us suppose that there is in man a power of beginning motion, and of acting with what has been of late called philosophical freedom; and let us suppose farther that the actions of such a man cannot possibly be foreknown; will there not yet be in the nature of things, notwithstanding this supposition, the same certainty of event in every one of the man's actions, as if they were ever so fatal and necessary? For instance, suppose the man, by an internal principle of motion, and an absolute freedom of mind, to do some particular action to-day, and suppose it was not possible that this action should have been foreseen yesterday, was there not nevertheless the same certainty of event as if it had been foreseen, and absolutely necessary? That is, would it not have been as certain a truth yesterday, and from eternity, that this action was in event to be performed to-day, notwithstanding the supposed freedom, as it is now a certain and infallible truth that it is performed? Mere certainty of event, therefore, does not in any measure imply necessity."[2] And surely it implies no contradiction to suppose, that every future event which in the nature of things is now certain, may now be certainly known by that intelligence which is omniscient. The manner how God can foreknow future events, without a chain of necessary causes, it is indeed impossible for us to explain; yet some sort of general notion of it may be conceived by us. "For, as a man who has no influence over another person's actions, can yet often perceive beforehand what that other will do; and a wiser and more experienced man, with still greater probability, will foresee what another, with whose disposition he is perfectly acquainted, will in certain circumstances do; and an angel, with still less degrees of error, may have a further prospect into men's future actions; so it is very reasonable to conceive that God, without influencing men's wills by his power, or subjecting them to a chain of necessary causes, cannot but have a knowledge of future free events, as much more certain than men or angels can possibly have, as the perfection of his nature is greater than that of theirs. The distinct manner how he foresees these things we cannot, indeed, explain; but neither can we explain the manner of numberless other things, of the reality of which, however, no man entertains a doubt."[3] We must therefore admit, as long as we perceive no contradiction in it, that God always knows all the free actions of men, and all other beings endued with liberty, otherwise he would know many things now of which he was once ignorant, and consequently his omniscience would receive addition from events, which has been already shown to be contrary to the true notion of infinity. In a being incapable of change, knowledge has nothing whatever to do with *before* or *after*. To every purpose of knowledge and power, all things are to him equally present. He knows perfectly every thing that is; and what to us is future he knows in the very same manner as he knows what to us is present.

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God infinitely perfect, all-sufficient, and omnipresent.

We have thus demonstrated the necessary existence of a being who is eternal, independent, unchangeable, omnipotent, free in his actions, and omniscient; and this is the being whom we worship as God. Eternity, independence, immutability, omnipotence, liberty, and omniscience, which seem to be all the natural attributes which we can discover in the divine nature, as they are conceived to be differently combined, make us speak of him in different terms. His enjoying in an absolute manner every conceivable power of perception, makes us call him a Being infinitely perfect. His being capable of no want, no defect, no unhappiness of any kind, denotes him to be all-sufficient in himself; and the unlimited exercise of his knowledge and his power demonstrates him to be omnipresent. That such a Being must be incomprehensible by us, and by every creature, is a truth self-evident; and yet in all ages men of the best intentions have been vainly attempting this impossibility. The manner of his omniscience, for instance, has been the subject of much disputation amongst those who ought to have reflected that they do not know how their own minds are present to their own bodies. The celebrated Dr Clarke and his adherents, who considered space as the *sine qua non* of all other things, insisted that God must be infinitely extended; and that, as wherever his substance is, there his attributes must be, it is thus that his knowledge and his power are present with every creature. But this notion labours under insuperable difficulties.

The manner of the divine omnipresence incomprehensible.

For, "if the divine substance be infinitely extended, then will there be part of it in this place and part in that. It must be commensurate with all particular beings, so that some will occupy more and some less of its dimensions. By this account it will be very proper and philosophical to say, that God is not in heaven, but only a part of him; and that an elephant or a mountain, a whale or a wicked giant, have more of the essence or presence of God with them, than the holiest or best man in the world, unless he be of equal size; all which, as has been well observed,[4] are at least harsh and grating expressions. As the attributes of the Divine Being must be considered in the same manner with his substance, we shall likewise, upon this notion of omnipresence, have a part of his knowledge and power in this place, and a part of them in that; and of these parts the one must be greater or less than the other, according to the dimensions of the place with which it is commensurate; which is a supposition that appears to us harsher, if possible, than even the former.

"Should it be said that the divine attributes are not to be considered as having parts (though we see not how they can be considered otherwise than as their subject), they must then exist completely in every point of this immense expansion. Be it so; and what follows? Why, every point of this infinitely expanded being will be omniscient and omnipotent by itself; an inch of it will have as much wisdom and power as a yard, a mile, or the whole; and, instead of one infinite wisdom and power, we shall have millions. For as these parts of the substance are conceived distinctly, and one individual part is not another, so must the attributes be likewise conceived, and the individual power and knowledge of one part be distinct from that of another." And if so, then it follows that one point of this expanded being has equal power and intelligence with the whole; so that the notion of extension

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[1] Clarke's Demonstration, &c. [2] Ibid. [3] Ibid.
[4] Watt's Essays; and Law's Inquiries into the Ideas of Space, Time, Immensity, &c.

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being necessary to God's presence with every creature, involves in it the most palpable contradiction. That God is at all times and in all places so present with every creature as to have an absolute knowledge of and power over it, is indeed capable of the strictest demonstration; but we think it great presumption to assign the particular mode of his presence, especially such an one as is neither agreeable to the nature of an absolutely perfect Being, nor in the least necessary to the exercise of any one perfection which he can be proved to possess. Philosophers and divines have offered several names for the manner in which God is present with his works; but we choose rather to confess that the manner of his presence is to us, and probably to every creature, wholly incomprehensible. Nor need we be surprised or staggered at this, when we reflect that the manner in which our own minds are present with our bodies is to us as incomprehensible as the manner in which the Supreme Mind is present with every thing in the universe. That our minds have a power over our limbs, we know by experience; but that they are not extended nor substantially diffused through them, is certain, because men daily lose arms and legs, without losing any part of their understanding, or feeling their energies of volition in the smallest degree weakened. But we need not pursue this subject farther. It has been confessed by one of the most strenuous advocates[1] for the extension of the Deity and all minds, that "there is an incomprehensibleness in the manner of every thing, about which no controversy can or ought to be concerned."

God's moral attributes result from his natural perfections.

The moral attributes of God may be deduced from his natural perfections, and are immediate consequences of them when exercised on other beings. They may be termed his secondary relative attributes, as they seem to be the perfection of his external acts rather than any new internal perfections. And though the existence of any moral quality or action is not capable of strict demonstration, because every moral action or quality, as such, depends upon the will of the agent, which must be absolutely free; yet we have as great assurance that there are moral qualities in God, and that he will always act according to these qualities, as the nature of the thing admits, and may be as well satisfied respecting it, as if it were capable of the most rigid demonstration. This important point, however, cannot be so clearly or so firmly established by abstract reasoning as by taking a scientific view of the works of creation, which evince the goodness, holiness, and justice of their Author, as well as his perfect wisdom and infinite power. The consideration, therefore, of the moral attributes of God, together with his providence and the duties thence incumbent on man, is the proper business of other articles.

How they ought to be conceived.

At present we shall only observe, that by reasoning *a priori* from his existence and his natural perfections, we must necessarily infer that his actions are all the result of unmixed benevolence. Every wise agent has some end in view in all his actions, it being the very essence of folly to act for no end; but there cannot be an end of action which is not either selfish or benevolent. Selfishness is the offspring of want and imperfection, and is therefore the source of most human actions; because men are weak and imperfect beings, capable of daily additions to their happiness. When the thief plunders a house at midnight, when the highwayman robs a traveller on the road, and even when the assassin murders the man who never injured him, it will be found that their actions spring not from an innate desire to inflict misery upon others, but from a prospect of reaping some advantage to themselves. The object of the thief and the robber is obvious; it is to gain money, which is the means of procuring the comforts of life. Even the assassin has always the same selfish end in view; either he is bribed to commit the murder, or he fancies that his horrid deed will remove an obstacle from the way to his own happiness. But they are not vicious men only who act from selfish considerations; for much of human virtue, when traced to its source, will be found to have its origin in the desire of happiness. When a man gives his money to feed the hungry and to clothe the naked, he believes that he is acting agreeably to the will of Him to whom he and the poor stand in the same relation, and he looks for a future and eternal reward. By continuing the practice, he soon acquires the habit of benevolence; after which, indeed, he looks for no further reward, when performing particular actions, than the immediate pleasure of doing good. This selfishness of man is the necessary consequence of his progressive state. But the Being who is independent, omnipotent, omniscient, and, in a word, possessed of every possible perfection, is incapable of progression, or of having any accession whatever made to his happiness. He is immutable, and must of necessity have been as happy from eternity, when existing alone, as after the creation of ten thousand worlds. When, therefore, he willed the existence of other beings, he could have nothing in view but to communicate some resemblance of his own perfections and happiness. That he had some end in view, follows undeniably from his infinite wisdom. That he could not have a selfish end, follows with equal certainty from his own infinite perfection; and as there is no medium, in the actions of a wise Being, between selfishness and benevolence, we must necessarily conclude that the creation was the result of unmixed benevolence or perfect goodness. The other moral attributes of the Deity, his justice, mercy, and truth, ought therefore only to be considered as so many different views of the same goodness in the Creator, and various sources of happiness to the creature. These are always subordinate to and regulated by this one principal perfection and brightest ray of the Divinity.

"Thus we conceive his justice to be exerted on any being no farther than his goodness necessarily requires, in order to make that being, or others, sensible of the heinous nature and pernicious effects of sin,[2] and thereby to bring them to as great a degree of happiness as their several natures are capable of. His holiness hates and abhors all wickedness, only as its necessary consequences are absolute and unavoidable misery; and his veracity or faithfulness seems to be concerned for truth, only because it is connected with and productive of the happiness of all rational beings; to provide the properest means for attaining which great end, is the exercise of his wisdom." Such is the view of God's moral attributes, which the abstract contemplation of his natural perfections necessarily suggests; and whether this way of conceiving them be not attended with less difficulty than the common manner of treating them under the notion of two infinites diametrically opposite, must be left to the judgment of the reader.

The origin of evil.

But if the Creator and supreme Governor of all things be a Being of infinite power, perfect wisdom, and pure benevolence, how came evil into the works of creation? This is a question which has employed the speculative mind from the first dawning of philosophy, and which will continue to employ it until our faculties be enlarged in a future state, when philosophy shall give place to more perfect knowledge. To these meditations, as has been well observed,[3] humanity is not equal. Volumes have been written on the subject; but we believe that the following extract from Dr Clarke contains all that can be advanced with cer-

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[1] Mr Jackson's Existence and Unity, &c. p. 110.

[2] Notes to King on Evil.

[3] Johnson's Review of a free Inquiry into the Origin of Evil.

Of the Being and Attributes of God.

tainty, and all that is necessary to vindicate the ways of God to man.

"All that we call evil," says that able reasoner,[1] "is either an evil of imperfection, as the want of certain faculties and excellencies which other creatures have; or natural evil, as pain, death, and the like; or moral evil, as all kinds of vice. The first of these is not properly an evil; for every power, faculty, or perfection, which any creature enjoys, being the free gift of God, which he was no more obliged to bestow than he was to confer being or existence itself, it is plain, that the want of any certain faculty or perfection in any kind of creatures, which never belonged to their nature, is no more an evil to them, than their never having been created or brought into being at all could properly be called an evil." To this we may add, that as no created being can be self-existent and independent, imperfection is unavoidable in the creation, so that the evil of defect (as it is most absurdly called) must have been admitted, or nothing could ever have existed but God. "The second kind of evil, which we call natural evil, is either a necessary consequence of the former, as death to a creature on whose nature immortality was never conferred; and then it is no more properly an evil than the former: or else it is counterpoised in the whole with as great or greater good, as the afflictions and sufferings of good men; and then also it is properly no evil: or else it is a punishment; and then it is a necessary consequence of the third and last sort of evil, viz. moral evil. And this arises wholly from the abuse of liberty, which God gave to his creatures for other purposes, and which it was reasonable and fit to give them for the perfection and order of the whole creation; only they, contrary to God's intention and command, have abused what was necessary for the perfection of the whole, to the corruption and depravation of themselves. And thus have all sorts of evils entered into the world, without any diminution to the infinite goodness of its Creator and Governor."

Whether the present be the best system possible.

But though evil could not be totally excluded from the universe, are we not authorized to infer, from the infinite power, wisdom, and goodness of the Creator, that the present system is upon the whole the very best system possible? Undoubtedly we are, if of possible systems there can be a best; but this is so far from being evident, that we think it implies a contradiction. A best of beings there is, viz. God, who is possessed of infinite perfections; but there cannot be a best of creatures or of created systems. To prove this, we need only reflect, that wherever creation stops, it must stop infinitely short of infinity; and that how perfect soever we conceive any creature or system of creatures to be, yet the distance between that and God is not lessened, but continues infinite. Hence it follows that the nature of God and his omnipotence is such, that whatever number of creatures he has made, he may still add to that number; and that however good or perfect the system may be on the whole, he might still make others equally good and perfect.

The dispute, whether a being of infinite power, wisdom, and benevolence, must be supposed to have created the best possible system, and the embarrassment of men's understandings about it, seem to have arisen from their taking the words, *good*, *better*, and *best*, for absolute qualities inherent in the nature of things, whereas in truth they are only relations arising from certain appetites. They have indeed a foundation, as all relations have, in something that is absolute, and denote the thing in which they are founded; but yet they themselves imply nothing more than a relation of congruity between some appetite and its objects. This is evident; because the same object, when applied to an appetite to which it has a congruity, is good; and when applied to an appetite to which it has no congruity, is bad. Thus, the earth and air to terrestrial animals are good elements, and necessary to their preservation; to those animals the water is bad, though it yet affords the best receptacle to fishes. Good, therefore, being relative to appetite, that must be reckoned the best creature by us which has the strongest appetites, and the surest means of satisfying them all, and securing its own permanent happiness. And though the substance of creatures is chiefly to be regarded as contributing to their perfection, yet we have no way of measuring the perfection of different substances, except by their qualities, that is, by their appetites, by which they are sensible of good and evil, and by their powers to procure those objects from which they receive that sense of things which makes them happy.

Of the Being and Attributes of God.

Origin of that question.

No system absolutely best.

It is plain, therefore, that whatever system we suppose in nature, God might have made another equal to it; his infinite wisdom and power being able to make other creatures equal in every respect to any that we know or can conceive, and to give them equal or even stronger appetites, and as certain or more certain ways of satisfying them. We see in many cases, that very different means will accomplish the same end. A certain number of regular pyramids will fill a space; and yet irregular ones will do it as well, if what we take from the one be added to another; and the same thing may be done by bodies of the most irregular and different figures in the same manner; and therefore we may very well conceive, that the answering of appetites, which is all the natural good that is in the world, may as well be obtained in another system as in this; provided we suppose, that where the appetites of the sentient beings are changed, the objects are also suited to them, and an equal congruity amongst the parts of the whole introduced. This is so easily conceived, that, in an indefinite number of possible worlds, we do not see why it may not be done in numberless ways by infinite power and wisdom.

God not necessitated to create the present in preference to other worlds.

If, then, it be plain that there might have been many other worlds, or even but one, equal to this in all respects as to goodness, there could be no necessity, either physical or moral, that God should create the one rather than the other, because nothing could make the one better, or to him more agreeable, than the other, except his own free choice. Either, therefore, God must be possessed of absolute freedom, or, amongst a number of possibilities equally perfect, he could not have made a choice, and so nothing would ever have been created. It is not, then, as Leibnitz and others argue, the natural and necessary goodness of some particular things, represented by the divine ideas, which determines God to prefer them to all others, if understood of his first act of producing them; but it is his own free choice, which, amongst many equal potential goods, makes some things actually good, and determines them into existence. When those are once supposed to exist, every thing or action becomes good which tends to their happiness and preservation; and to suppose that their all-perfect Author had any other end in view than their preservation and happiness, is the same absurdity as to suppose that knowledge may produce ignorance; power, weakness; or wisdom, folly. (H. H. H. H.)

[1] Demonstration of the Being and Attributes of God.

Metastasio.

METASTASIO, PIETRO BUONAVENTURA, one of the great masters of modern Italian poetry, was born at Rome on the 3d of January 1698. Though the son of a poor artisan named Trapassi, he had nevertheless for his godfather the Cardinal Pietro Ottoboni, who gave to the infant his own Christian name. The young Trapassi had scarcely attained the age of ten, when his poetical talent displayed itself by his surprising improvisations. One day when a crowd of persons had assembled around him in the Campus Martius, the celebrated jurisconsult Gravina approached, and having listened to his performance, bestowed on it some just commendations; after which he offered the boy a piece of money, which the latter nobly refused. Gravina, not less delighted with his spirit than charmed with his genius, went immediately to the father of the boy, and without much difficulty persuaded him to abandon all concern about the education of his son, whom he undertook to instruct; and, in point of fact, the generous jurisconsult taught him the elements of Greek, Latin, and Italian literature. By a singular caprice, the young man changed his name of Trapassi into that of *Metastasio*, which, in Greek, has the same signification; and, according to the Roman usage, he prefixed to it the title of Abbate. Gravina, though chiefly devoted to the study of legislation, was also addicted to poetry, in the cultivation of which he sought relief from graver and more laborious pursuits. Being particularly attached to the Greek drama, he aspired to the glory of reviving it in Italy; and he had already published five tragedies, on the ancient model, when he became convinced that his pupil was much better qualified than himself for the execution of this grand project. At his instigation, accordingly, Metastasio, though as yet only fourteen years of age, composed his *Giustino*, the great defect of which is too servile an imitation of the ancients; and at the same time, for his own satisfaction, he amused himself in translating portions of the Iliad into Italian verse. Nevertheless, Gravina, concerned about the fortune of his pupil, wished that with the cultivation of letters Metastasio should combine the study of jurisprudence. To this austere occupation the young poet sacrificed with regret the time which he was forced to take from the muses; but Gravina died suddenly, leaving the greater part of his property to his adopted son; and Metastasio, though not yet twenty years of age, thus found himself master of a considerable fortune. In an elegy entitled *La Strada della Gloria*, he bewailed the death of his benefactor, for whose memory he cherished the most ardent and sincere regard; but the numerous acquaintance whom his talents and fortune procured him soon distracted his attention, whilst they consumed his time; and so inconsiderately did the youth abandon himself to this agitated life, that, at the end of two years, he found he had made more creditors than friends, the bequest of his patron being by this time nearly exhausted.

In these circumstances, he took the resolution of quitting Rome; and, in 1721, went to establish himself at Naples, in which city he began to devote himself entirely to the theatre. Here a distinguished actress, called La Romanina, contributed so much to the success of his first attempts in the drama, that his gratitude for her exertions soon assumed the character of attachment. Apostolo Zeno, Corneille, and Racine, now became the objects of his continual study. This is attested by several of his Italian biographers, particularly by Mauro Boni, who has written with great care the literary life of the poet; and hence it is not easy to discover upon what authority Schlegel has alleged that Metastasio, in order to preserve his originality pure, boasted of having carefully avoided consulting the masterpieces of the French stage. It was also at Naples, and for La Romanina, that the young poet composed his famous *Didone abbandonata*, which was represented for the first time in the year 1724. The success of this production is inconceivable. All the great cities of Italy vied with one another in the pomp and splendour of the representations; and the country was deserted by its population, which rushed in a body to witness the performance of the *Didone*. Being now in a condition to satisfy his creditors, Metastasio lost no time in returning to Rome. In the eternal city he had no other residence than that of La Romanina, who repeated and sung his verses as soon as he composed them.

Metastasio.

His reputation having now become general, the Emperor Charles VI. in the year 1729 offered him the title of *Poeta Cesareo*, or imperial laureat, with an annual allowance of three thousand florins. In this situation he had the honour to succeed Apostolo Zeno, who himself declared that a better choice could not be made. Before adopting a new country, Metastasio did not neglect the comforts of his family, having secured an asylum for the declining years of his father, and made a provision for each of his sisters. To them also he made over all his income in Italy, and he constantly assisted with his counsel and with his means a younger brother, who followed the profession of advocate at Rome. At length it became necessary to quit La Romanina, and this separation cost him a severe struggle. Having arrived at Vienna in the spring of the year 1730, he had immediately the honour of being presented to the emperor at the castle of Laxemburg. At the particular request of the master of ceremonies to the apostolic nuncio, Niccolo de Martinez, he took up his abode in the residence of that functionary; and it was in this same house that, some years afterwards, fortune brought together, in two chambers situated the one above the other, two men who have filled Europe with their renown, Metastasio and Haydn. But the only benefits which the great musician, then young and poor, derived from this fortuitous conjunction, were a knowledge of the Italian language, and some counsels as to the best mode of attaining the truly beautiful in art.

The Italian friends of the new imperial laureat had predicted to him, when he quitted Rome, that the cloudy atmosphere of Germany would freeze his imagination; but so far was this from being the case, that it never showed itself more ardent or more prolific. Indeed, one cannot help, even now, feeling some surprise in running over the list of the various works which he composed during the first years of his residence at Vienna, and amongst which may be found several of those that have contributed most to extend his reputation. Such are the *Giuseppe Riconosciuto*, the *Demofonte*, and also the *Olimpiade*, which all Italy agreed to surname the divine. A severe affliction, however, served to temper the exultation of success. His faithful friend La Romanina, the ministering angel of his genius, had sunk into a premature grave. But even in this sorrowful occurrence he found an occasion for exemplifying the innate excellence of his character. That celebrated cantatrice had, by her will, left him a legacy of twenty-five thousand Roman crowns, a bequest which he generously renounced in favour of poor Bulgurelli, the almost forgotten husband of La Romanina.[1]

[1] "Whether Metastasio's connexion with the Romanina was purely platonic," says Dr Burney, "or of a less seraphic kind, I shall not pretend to determine; but the husband residing in the same house with them, both at Naples and at Rome, and the friendly manner in which the poet always mentioned him in his letters to the wife, with the open manner in which he expressed his affliction to him after her death, would, in England, be thought indications favourable to conjugal fidelity." We do not know why they should not be thought so in Italy as well as in England. "But a chaste actress and opera singer," he adds, "is a still more uncommon phenomenon in Italy than in Britain." The truth of this alleged fact may, however, be doubted; and, at all events, we have not met with a vestige of evidence to justify the insinuation which it is here employed to convey.

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Metastasio was engaged upon a new piece, *Attilio Regolo*, when the unexpected death of his august protector disconcerted all his hopes. The Emperor Charles VI. had scarcely been consigned to the tomb when his inheritance was disputed by several powers. His daughter, Maria-Theresa, a fugitive, had no longer a court, and still less a theatre. Metastasio, however, took no steps to employ his talents otherwise, and even celebrated by an ingenious production, *Amor Prigionero*, the birth of the prince who afterwards became Joseph II. It was at this period that Metastasio, though not yet more than forty-three, felt the first symptoms of that nervous malady of which he complained until the close of his career. He soon experienced the most acute pains, and, to aggravate his sufferings, malevolence and calumny tracked his steps. He wished to return to Italy, but could not accomplish his purpose. Having no longer occasion to labour for the theatre, which was shut in consequence of the Seven Years' War, he amused himself with composing a number of cantatas in honour of the young archduchesses; produced *La Contessa de Numi*, in which, whilst celebrating the birth of the son of the Dauphin, he contrives to pay some graceful and flattering compliments to the French nation; and also translated several satires of Juvenal and Horace. In 1760, his muse roused herself to celebrate the marriage of Joseph II. His opera of *Alcide in bivio* delighted the whole court, which fancied in this production it discovered frequent allusions to the character of the young prince.

Being already affluent, and loaded with the honourable marks of regard which had been bestowed upon him, Metastasio no longer stood in need of ordinary favours; but he was nevertheless very sensible of the distinction now conferred upon him by Maria-Theresa, who addressed to him several notes which were written with her own hand, and filled with expressions of kindness and good will. A few of these flattering billets have been preserved. They are written in French; and in one of them this great princess says to the poet, "Mon ancien maître fait la gloire de notre siècle, et plus encore de ceux à qui il s'est voué." By degrees, Metastasio withdrew entirely from the world, and discontinued publication; but he by no means abandoned the cultivation of letters. He occupied himself with learned analyses of the Poetics of Aristotle and of Horace; and embodied in notes his luminous observations on Æschylus, Euripides, Sophocles, and Aristophanes. One of the enjoyments of his old age was the publication of the magnificent edition of his works, which was printed at Paris in 1780, under the direction of the learned Pezzana. Several celebrated pieces in that beautiful collection, particularly the *Didone*, the *Adriano*, the *Semiramide*, and the *Alessandro*, were re-touched with extreme care by their illustrious author. He had, in his library, more than forty editions of his works, published at different periods in the first cities of Italy; but he called that of Paris the glory and the crown of his old age.

These literary distinctions were to him the suitable reward of his long-continued labours. He never aspired to any of those dignities which form the ordinary objects of vulgar ambition. The Emperor Charles VI. several times wished to confer upon him the titles of baron and aulic councillor; but he always replied that his best title was that of poet to his imperial majesty. The empress also offered him the cross of St Stephen; but he declined the honour, excusing himself by saying, that he had no time to perform the duties of knighthood. When Corilla was crowned in the Capitol, Maria-Theresa expressed a desire to see admitted to the same honour the man who for sixty years had delighted Europe with his harmonious verses; and Pope Clement XIV. warmly responded to the wish of the empress. But the poet was inflexible; he replied that he was too old to ascend the Capitol. Nevertheless the most celebrated writers of the age rendered him homage. Voltaire compared certain scenes of Metastasio to the most sublime productions of Greece; he judged them "worthy of Corneille when he is not a declaimer, and of Racine when he is not feeble." Rousseau, in his *Nouvelle Heloise*, declared that Metastasio was "the only poet of the heart, the only genius formed to excite emotion by the charm of poetical and musical harmony." This great writer merited a still higher encomium; he never replied with the least bitterness, even to the most unjust criticisms; and he was always the first to encourage talent wherever he discovered it. Entertaining a deep conviction of the truths of religion, Metastasio observed its precepts without ostentation; and in his old age, this sincere and unaffected piety enabled him to support his sufferings with greater patience and resignation. In the month of February 1780, he believed that his end was approaching, and wishing to consecrate to God the last efforts of his poetical genius, he traced with a trembling hand, but a devout heart, the touching verses beginning, *Eterno genitor*, &c. His strength returned, however, and he had the grief to survive his august benefactress, who died in the month of November the same year. He was so sincerely attached to her, that, on several occasions, he was heard to exclaim, "Why have I not descended to the tomb with my excellent mistress?" But a great consolation was reserved for him in his last days, inasmuch as he lived to witness the arrival of Pope Pius VI. at Vienna. The sovereign pontiff honoured him with many proofs of his esteem, and, as a last token of regard, caused the nuncio Gerampi to convey to him, upon the day of his death, the apostolical benediction. Metastasio expired on the 2d of April 1782, having attained the advanced age of eighty-four years and three months. He was interred in the church of St Michael; and, notwithstanding the formal request expressed in his will, his obsequies were magnificent. M. de Martinez, his heir, immediately caused to be struck in memory of his illustrious friend a medal, with this legend, *Sophocli Italo*. Of all the portraits of him extant, none is so like the original as that of Heiner, engraved by Mansfield, except it be the bust executed at Vienna by Vinnazar. Metastasio possessed an imposing figure; he was tall and well-proportioned; and his dark eyes had a striking expression. Fortune, indeed, appears to have taken a pleasure in loading him with her favours. Independently of a sumptuous establishment, and a superb library, his succession realized a capital of more than three hundred thousand francs, or above L.12,000 sterling.

The poetical works of Metastasio consist of sixty-three lyrical tragedies and operas of various kinds; twelve oratorios; forty-eight cantatas or lyric scenes; a vast number of elegies, idylls, canzonette, sonnets, and such like compositions; and, lastly, translations in verse from Latin authors, including one of Horace's *Art of Poetry*. Amongst his works in prose, besides those already mentioned, may be reckoned a very extensive, interesting, and instructive correspondence. Metastasio has found in France several imitators, who have profited by his dramatic conceptions, particularly Belloy and Delrieu; and Labouisse has likewise imitated in French verse his cantatas, which, in as far as respects their ordinary subject, may as well be classed amongst the pastorals as referred to the head of lyric compositions. From the year 1733 to the present time, there have been innumerable editions of the works of Metastasio, many of them exceedingly defective and incomplete. The most esteemed are the following, viz. 1. Paris, 1755, in twelve vols. 8vo, under the direction of Calzabigi, and dedicated to Madame de Pompadour; 2. Turin, 1757, in fourteen vols. 4to, printed at the royal press, from the preceding edition; 3. Paris, 1780, in twelve vols. large 8vo, under the direction of Pezzana, who accented the prosody

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for the benefit of French readers; 4. Genoa, 1802, in six thick vols. 8vo, small character, an edition superintended by the poet Massuccio, who enriched it with the posthumous works and unedited pieces published at Vienna in 1795, by Count Ajala, but omitted the correspondence; 5. Padua, 1810. There appeared at Paris in 1761 a French translation of the operatic tragedies by Richelet, in twelve vols. 12mo.

The Italians have almost deified Metastasio; but, excepting on one point, where they have a sort of privative jurisdiction, we may be permitted to question the propriety of this idolatry. In relation to his style, they are the natural, perhaps the only competent judges; and this style they regard as a model of purity, elegance, and harmony. "The style of Metastasio," says an Italian critic, "never fails to please those who give way to their own emotions, more than persons of profound meditation; and I would rather be accused of partiality to him whom I venerate and love, than ranked with cold philosophers and deep thinkers, whom I may respect, but cannot admire." It is in his pieces borrowed from Sacred Scripture that Metastasio has most strikingly exemplified the great beauties of his style. As to the other attributes of his genius, they have been variously estimated by critics. "I know not amongst the moderns," says Laharpe in his *Cours de Litterature*, "a writer more precise than Metastasio. A people who may boast of such a poet cannot say that, if he has attached himself exclusively to music, it is because the words are bad. A lively and intelligent people could never be insensible to the genius of Metastasio, displayed in the interest of the situations, and in the beauty of the dialogue and style. Nevertheless, it was at the court of Vienna, and not in his own country, that this celebrated writer found recompense and honour." But a celebrated German critic, William Schlegel, in his Course of Dramatic Literature, has evinced a much deeper insight into the dramatic system of the Italian poet, and more judiciously discriminated the merits and defects of his works. "The reputation of Metastasio," says he, "has eclipsed that of Apostolo Zeno, because, in proposing to himself the same object, he had a much more flexible talent, and knew better how to accommodate himself to the convenience of the musician. Perfect purity of diction, united with sustained grace and elegance, have caused Metastasio to be regarded by his countrymen as a classical author, and, so to speak, as the Racine of Italy. He is pre-eminently distinguished for exquisite sweetness in the verses which he intended to be sung. Perhaps no poet ever possessed in the same degree the power of concentrating, in a narrow compass, all the most touching traits of a pathetic situation. The lyrical monologues at the end of the scenes are the harmonious expression, at once just and concise, of a particular disposition of the soul. It must be confessed, however, that Metastasio never paints the passions except in very general colours; he does not amalgamate with the sentiments of the heart any thing that appertains to the individual character, or is derived from universal contemplation. Thus his pieces are not very powerfully conceived. When you have read a few of them, you know them all. Yet we must not be too severe. The heroes of Metastasio, it is true, are all gallants; in his heroines, too, delicacy often degenerates into mawkish affectation; but perhaps this effeminate poetry has been blamed from a want of proper attention to the nature of the opera." Justice also requires that, in the peculiar genius of the opera, we should recognise the inevitable cause of that languor and incongruity which too frequently disfigure the most beautiful productions of Metastasio. It is from yielding to the exigencies of this particular species of composition that he has so often violated the law of the unities, disfigured the characters of his heroes, and broken the continuity of his style. He is less excusable in the lavish use of antitheses; but this affectation is a general vice amongst the poets of his country. The lyrical drama, in general, requires a fortunate consummation or denouement; and how often, in order to obey this usage, and to have a brilliant chorus, or a final divertissement, has the poet found himself under the necessity of inverting the tragic action, and denaturalizing his characters? It is painful to think that so many sacrifices to a frivolous fashion have, from the immense development of the musical system which has since taken place, been made altogether in vain.

Metastasis || Metempsychosis.

Of the musical productions of Metastasio two have been engraved; one containing a collection of *Canzoni*, and the other entitled *Arie Sciolte* and *Coro con Sinfonia*. The famous duet *Grazie agl'Inganni tuoi* has not yet, as far as we know, been published. The *Pensieri di Metastasio, ovvero Sentenze e Massime estratte dalle sue Opere*, were collected and published at Paris in the year 1804. (A.)

METASTASIS, in *Medicine*, a transposition or settlement of a humour or disease in some other part. Sometimes it signifies such an alteration of a disease as is succeeded by a solution.

METELLUS, the surname of the family of the Cæcilii at Rome, of whom the best known were the following. First, a general who defeated the Achæans, took Thebes, and invaded Macedonia. Second, Q. Cæcilius, who rendered himself illustrious by his successes against Jugurtha, king of Numidia, from which he received the surname of Numidicus. Another of this name, being high priest, saved from the flames the palladium when Vesta's temple was on fire. He lost his sight and one of his arms in the action; and the senate, to reward his zeal and piety, permitted him to be always drawn to the senate-house in a chariot, an honour which no one had ever before enjoyed. He also gained a great victory over the Carthaginians. Fourth, Q. Cæcilius Celer, who distinguished himself by his spirited exertions against Catiline. He married the sister of Clodius, who disgraced him by her incontinence and lasciviousness, and died fifty-seven years before Christ. He was greatly lamented by Cicero, who shed tears at the loss of one of his most faithful and valued friends. Fifth, L. Cæcilius, a tribune in the civil wars of Cæsar and Pompey. He favoured the cause of Pompey, and opposed Cæsar when he entered Rome with a victorious army. He refused to open the gates of Saturn's temple, in which were deposited great treasures; upon which they were broken open by Cæsar, and Metellus retired when threatened with death. Sixth, Q. Cæcilius, a warlike general who conquered Crete and Macedonia, and was surnamed Macedonicus. He had four sons, of whom three were consuls, and the other obtained a triumph, all during their father's lifetime. Seventh, a general of the Roman armies against the Sicilians and Carthaginians. Before he marched, he offered sacrifices to all the gods excepting Vesta; a neglect for which the goddess was so incensed that she demanded the blood of his daughter Metella. When Metella was going to be immolated, the goddess placed a heifer in her stead, and carried her to a temple at Lanuvium, of which she became the priestess. Another, surnamed Dalmaticus, from his conquest over Dalmatia, in the year of the city 634. Cimber, one of the conspirators against Cæsar. It was he who gave the signal to attack and murder the dictator in the senate-house. Lastly, Pius, a general in Spain against Sertorius, on whose head he set a price of a hundred talents and twenty thousand acres of land.

METEMPSYCHOSIS, formed from *μετα*, *beyond*, and *ἐμψυχω*, *I animate* or *enliven*, in the ancient philosophy, signified the passage or transmigration of the soul of a man after death into the body of some other animal. Pythagoras and his followers held, that after death men's souls passed into other bodies of different kinds, according to the manner of life which they had led. If they had been

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vicious, they were imprisoned in the bodies of miserable beasts, there to do penance for several ages, at the expiration of which they returned again to animate human forms. But if they lived virtuously, the body of some happier brute, or even of a human creature, was destined to be their new habitation. What led Pythagoras into this opinion was, the persuasion which he had that the soul was not of a perishable nature, and from which he concluded that it must remove into some other body upon its abandoning its actual habitation. Lucan treats this doctrine as a kind of officious lie, contrived to mitigate the apprehension of death, by persuading men that they had changed their lodging, and only ceased to live in order to begin a new life. Reuchlin denies this doctrine, and maintains that the metempsychosis of Pythagoras implied nothing more than a similitude of manners, desires, and studies, which formerly existed in some person deceased, and were subsequently revived in another. Thus, when it was said that Euphorbus was revived in Pythagoras, no more was meant than that the martial virtue which had shone in Euphorbus at the time of the Trojan war, was now in some measure revived in Pythagoras, by reason of the great respect he bore to the *athletæ*. For those people, wondering how a philosopher should be so much taken with men of the sword, he palliated the matter by saying that the soul of Euphorbus, meaning thereby his genius, disposition, and inclinations, were revived in him; and this gave occasion to the report that the soul of Euphorbus, who perished in the Trojan war, had transmigrated into Pythagoras. Ficinus asserts that what Plato said of the migration of a human soul into a brute, is allegorically said, and to be understood, only of those manners, affections, and habits which have degenerated into a beastly nature by vice. Serranus, though he allows some force to this interpretation, yet rather inclines to understand the metempsychosis as meaning a resurrection. Pythagoras is said to have borrowed the notion of a metempsychosis from the Egyptians; but others maintain that he received it from the ancient Brahmins. It is still retained amongst the Banians and other idolaters of India and China, and forms the principal foundation of their religion; indeed, so bigoted are they to this tenet, that they not only forbear eating any thing which has life, but many of them even refuse to defend themselves against wild beasts. They burn no wood, lest some little animalcule should be consumed in it; and are so very charitable, that they will redeem from the hands of strangers any animals which they find ready to be killed.

METEMPTOSIS (from *μετα*, *post*, and *πιπτω*, *cado*, I fall), a term in chronology, expressing the solar equation necessary to prevent the new moon from happening a day too late. Metemptosis is contradistinguished from *proemptosis*, which signifies the lunar equation necessary to prevent the new moon from happening a day too soon. As the new moons run a little backwards, that is, come a day too soon at the end of 312 years and a half, by the proemptosis a day is added every 300 years, and another every 2400 years. On the other hand, by the metemptosis, a bissextile day is suppressed each 134 years, that is, three times in 400 years. These alterations are never made but at the end of each century, that period being very remarkable, and rendering the practice of the calendar easy. There are three rules for making this addition or suppression of the bissextile day, and, consequently, for changing the index of the epacts. First, when there is a metemptosis without a proemptosis, the next following or lower index must be taken. Secondly, when there is a proemptosis without a metemptosis, the next preceding or superior index is to be taken. Thirdly, when there are both a metemptosis and a proemptosis, or when there is neither the one nor the other, the same index is preserved. Thus, in 1600, we had D; in 1700, by reason of the metemptosis, C was taken; in 1800, there was both a proemptosis and a metemptosis, therefore the same index was retained. In 1900 there will be a metemptosis again, when B will be taken; and this will be preserved in 2000, because there will then be neither the one nor the other. This is as far as we need compute for it. But Clavius has calculated a cycle of 301,800 years, at the end of which period the same indices will return in the same order.

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METEOR (by the Greeks called *μετεωρα*, *sublime* or *high raised*; by the Latins, *impressiones*, as making signs or impressions in the air) commonly denotes any bodies in the air which are of a transitory nature. Hence it is extended to the phenomena of hail, rain, snow, and thunder; but is most commonly confined to those unusual and fiery appearances named falling stars, *ignes fatui*, *auroræ boreales*, and the like.

METEOROLITE. This term is derived from the Greek *μετεωρα*, *a meteor*, and *λιθος*, *a stone*, and denotes a stony substance, exhibiting peculiar characters, and the descent of which to the earth is usually accompanied by the appearance and explosion of a fire-ball.

Luminous meteors have, in all ages, been observed in the atmosphere. It is also well known that their disappearance has frequently been attended with a loud noise; but that they should moreover terminate in the fall of one or more solid bodies to the earth's surface, is a position so repugnant to our ordinary conceptions of the tenor of physical events, that we cannot admit it as a fact upon slight or scanty evidence. With all proper deference, however, to some philosophers of name, we are not prepared to assert that it implies impossibility. For who has explored the higher regions of the atmosphere, or who knows what may take place beyond its precincts? If a solid result from the combination of two aeriform substances, as the muriatic acid and ammoniacal gases; if oxygen, the properties of which are most familiar to us in the state of gas, can undergo fixation; and if fluids can pass into crystalline forms; is it too bold to presume, that the same or similar processes, effected in the grand laboratory of the atmosphere, may be within the range of possible occurrences? Every thing around us proclaims that matter is subject to incessant change. New forms and new modifications are ever springing into being. Can we doubt, then, that the same particles, as they may happen to be affected or influenced by various circumstances, may exist in the state of gas, of aqueous vapour, or of a concrete mass?

Again, it will not surely be seriously maintained, that, from the rarity of a phenomenon, we are warranted to infer its non-existence. The appearance of a comet is a rare, but certainly not a fictitious occurrence. Nay, we may safely advance a step farther, and assert, that the existence of a phenomenon, if otherwise well attested, cannot be disproved by our inability to explain it. How multiplied, in fact, are the subjects, even of our daily and hourly observation, which we cannot satisfactorily expound? We cannot say why a small seed should gradually unfold into a large tree, why flame should produce heat, why the hand should act in immediate subserviency to the will, or why a contusion of the brain should induce stupor, alienation of mind, or death. It is one thing to prove a fact, and it is another to account for it.

From these premises it follows, that we are not entitled to reject the existence of meteoric stones, provided this be established by valid testimony. Should the historical evidence, upon a fair and dispassionate review, be deemed conclusive, we may afterwards examine the theories which have been proposed for the solution of the appearance.

We are not aware that any passage can be cited from the books of the Old Testament in direct corroboration of the descent of stones from the atmosphere. The ingenious and fanciful Edward King, indeed, in his Remarks con-

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cerning the Stones said to have fallen from the Clouds, both in these Days and in Ancient Times, adverts to the 13th verse of the xviiith Psalm: "The Lord also thundered in the heavens, and the Highest gave his voice; hailstones and *coals of fire*." This last expression has, no doubt, been conjectured to denote real hard bodies, in a state of ignition; and the Greek term employed by the cautious Seventy-two rather favours such an interpretation. The same expression, however, occurs in the preceding verse, without admitting this interpretation, and the phrase seems to be only a figurative mode of describing lightning. In the sober latitudes of the north, and even in ordinary colloquial language, we talk of "balls of fire," and "thunderbolts," without any reference to solid matter. Mr King likewise quotes the 11th verse of the xth chapter of Joshua: "And it came to pass, as they fled from before Israel, and were in the going down to Beth-horon, that the Lord cast down *great stones* from heaven upon them unto Azekah, and they died; they were more which died with hailstones than they whom the children of Israel slew with the sword." Here the expression "great stones" is much less equivocal than "coals of fire;" yet the context hardly allows us to doubt, that the great stones were really hailstones, or rather, perhaps, lumps of ice consolidated in the atmosphere, such as occasionally fall in hot countries, and such as alarmed the whole of Paris and its neighbourhood in the year 1788. At any rate, the slaughter of the Canaanites is represented as resulting from the special interposition of divine power, and the consideration of miracles is irrelevant to our present purpose.

If from sacred we turn to the early period of profane history, we shall find the annals of public events very copiously interspersed with notices of strange appearances, many of which may be safely ascribed to the ascendency which superstition long obtained over the human mind. The scepticism of the learned is, however, sometimes not less injudicious and indiscriminate than the credulity of the savage; and he who should resolve every extraordinary event which is recorded by the writers of Greece and Rome into a "cunningly-devised fable," would not be less reprehensible for want of candour than the untutored rustic, who yields his assent to every alleged miracle, may be taxed with want of discernment.

Although these general positions can scarcely admit of any dispute, it becomes extremely difficult, after a lapse of many ages, and in the collation of marvellous records, to separate truth from falsehood. In our attempts to prosecute this analytical process, we may sometimes advance a certain length with perfect security, without being able to trace uniformly the precise lines of demarcation. Thus, in regard to the topic at present in discussion, we are aware that in various periods of the world the vulgar have ascribed a celestial origin to stones of a peculiar configuration; as to certain modifications of pyrites, to belemnites, orthoceratites, and others, which the subsequent observations of naturalists have proved to be of mineral formation; and to the heads of arrows and sharpened flints, which have been fashioned by the hand of man, and which, accordingly, we are authorized to exclude from the ex-terrestrial catalogue. But when substances dissimilar to these, and not coinciding in any one character or circumstance with modern specimens of atmospherical stone, are reported by the ancients to have fallen from the clouds, the distance of ages and the defectiveness of the documents may powerfully affect our appreciation of the reputed evidence. When, therefore, we shortly touch upon a few of the many instances which might be quoted from the annals of antiquity, we mean not to vouch for the truth even of these particular instances, but merely to admit their probability, and the weight which the mention of them may be considered to add to that of subsequent and recent narrations.

Through the midst of fable which envelopes the history of the *bætuli*, we discern some characters which correspond with those of meteorolites. Thus, in the Λιθικα, a poem falsely ascribed to Orpheus, the σιδηριτης, which Falconet properly classes with the *bætuli*, is said to be "rough, heavy, and black." Damascius, in an extract of his life of Isidorus, preserved by Photius, relates, that the *bætuli* fell on Mount Libanus, in "a globe of fire." A fragment of Sanchoniathon, preserved by Eusebius in his *Præparatio Evangelii* (i. 10), moreover informs us, that these stones were fabricated by the god Uranus or Heaven, one of whose four sons was named Bætul. May not this mythological genealogy be regarded as merely emblematical of their descent from the upper regions of the atmosphere? In the same chapter we are told that Astarte found a "star" which had "fallen from heaven," and honoured it with consecration in the city of Tyre. The stone denominated "the mother of the gods," if we can believe Appian, Herodian, and Marcellinus, "fell from heaven." Aristodemus, cited by the Greek scholiast on Pindar, asserts that it fell encircled by fire, upon a hill, at the feet of the Theban bard. It is said to have been of a black colour, and of an irregular shape. Herodian expressly declares, that the Phœnicians had no statue of the sun, polished by the hand, but only a certain stone, circular below, and terminated acutely above, in the form of a cone, of a black colour, and that, according to report, it "fell from heaven," and was regarded by the people as the image of the sun.

Amongst various instances which might be selected from Livy, is that of a shower of stones on the Alban Mount, in the reign of Tullus Hostilius, or about six hundred and fifty-two years before the birth of Christ. When the senate were told that it had rained stones, they doubted the fact, and deputed commissioners to inquire into the particulars. They were then assured that stones had really fallen, "haud aliter quam quum grandinem venti glomeratam in terras agunt." On this occasion, the historian mentions that similar events were celebrated by a festival of nine days. "Mansit solenne, ut quandocunque idem prodigium nuntiaretur, feriæ per novem dies agerentur."

But one of the most remarkable cases which occurs in the records of antiquity, is that which is mentioned in the fifty-eighth chapter of the second book of Pliny's Natural History, of a large stone which fell near Egospotamos, in Thrace, in the second year of the seventy-eighth Olympiad, or, according to our chronology, about four hundred and sixty-seven years before the Christian era. Pliny assures us that this extraordinary mass was still shown in his day; and that it was as large as a cart, and of a burned colour. The Greeks pretended that it had fallen from the sun, and that Anaxagoras had predicted the day of its arrival upon the earth's surface. According to Plutarch, in the life of Lysander, the inhabitants of the Chersonesus held the Thracian stone in great veneration, and exhibited it as a public show. His account of its first appearance is chiefly extracted from the relation of Daimachus of Platææ, and may be thus translated: "During seventy-five successive days before the stone fell, a large fiery body, like to a cloud of flame, was observed in the heavens, not fixed to one point, but wandering about with a broken irregular motion. By its violent agitation, several fiery fragments were forced from it, impelled in various directions, and darted with the velocity and brightness of so many shooting stars. After this body had fallen on the Chersonesus, and the people had assembled to examine it, they could find no inflammable matter, nor the slightest trace of combustion, but a real stone, which, though large, by no means corresponded to the dimension of the flaming globe which they had seen in the sky, but appeared to be only a piece detached from it." Daimachus, it is true, may, upon this occasion, have given way to his reputed love

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of the marvellous; and we can easily believe that the "seventy-five continuous days" is either an error of the copyist, or an original exaggeration; yet, from the marked coincidence of some of the circumstances with those more fully detailed in the sequel, there arises the presumption that a meteorolite really fell at the place and time above mentioned.

From this period till near the close of the fifteenth century, any historical notices which we have been enabled to collect are so vague and scanty, that, in this abridged view of the subject, we may pass them over in silence.

Professor Bantenschoen, of the central school of Colmar, first directed the attention of naturalists to some of the old chronicles, which commemorate, with much naiveté, and in the true spirit of the times, the fall of the celebrated stone of Ensisheim. The following account accompanied this very singular mass, when it was suspended in the church. "In the year of the Lord 1492, on Wednesday, which was Martinmas eve, the 7th of November, there happened a singular miracle; for, between eleven o'clock and noon, there was a loud peal of thunder, and a prolonged confused noise, which was heard to a great distance, and a stone fell from the air, in the jurisdiction of Ensisheim, which weighed 260 pounds, and the confused noise was, moreover, much louder than here. There a child saw it strike on a field, situated in the upper jurisdiction, towards the Rhine and Inn, near to the district of Gisgard, which was sown with wheat; and did it no harm, except that it made a hole there; and then they conveyed it from that spot, and many pieces were broken from it, which the landvogt forbade. They, therefore, caused it to be placed in the church, with the intention of suspending it as a miracle, and many people came hither to see this stone. So there were remarkable conversations about this stone; but the learned said that they knew not what it was, for it was beyond the ordinary course of nature that such a large mass should smite the earth from the height of the air; but that it was really a miracle of God, for before that time never any thing was heard like it, nor seen, nor described. When the people found that stone, it had entered into the earth to the depth of a man's stature, which every body explained to be the will of God that it should be found; and the noise of it was heard at Lucerne, at Villing, and in many other places, so loud, that it was believed that houses had been overturned. And as the king (Maximilian) was here, the Monday after St Catherine's day, of the same year, his royal excellency ordered the stone which had fallen to be brought to the castle, and after having conversed a long time about it with the noblemen, he said the people of Ensisheim should take it, and order it to be hung up in the church, and not allow any body to take any thing from it. However, his excellency took two pieces of it, of which he kept one, and sent the other to the Duke Sigismund of Austria; and they spoke a great deal about this stone, which they suspended in the choir, where it still is, and a great many people came to see it."

Again, Trithemius, in his Hirsaugiensian Annals, employs language to this effect: "In the same year, on the 7th day of November, in the village of Suntgaw, near the townlet of Ensisheim, not far from Basil, a city of Germany, a stone, called a thunder-stone, of a prodigious size, for we know from eye-witnesses that it weighed 255 pounds, fell from the heavens. Its fall was so violent that it broke into two pieces. The most considerable is still exhibited at the door of the church of Ensisheim, suspended by an iron chain, as a proof of the fact which we have mentioned, and to preserve it in the public recollection." We learn also from Paul Lang, "that there arose a furious storm on the 7th of November 1492, and that whilst the thunder roared, and the heavens appeared all on fire, a stone of enormous size fell near Ensisheim. Its form was that of the Greek delta, with a triangular point. They still show it at Ensisheim as an astonishing phenomenon."

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It is worthy of observation that these chroniclers lived at the period which they assign to the descent of the stone, and that, although their names are hastening to oblivion, Trithemius yielded to few of his contemporaries in labour and learning; whilst Lang, a German Benedictine, had travelled in search of historical monuments, arraigned the license of the Catholic clergy, and applauded the independence of Luther and Melancthon.

We are fully aware that Barthold has laboured to convince his readers (*Journal de Physique*), that the far-famed mass of Ensisheim is merely argillo-ferrugineous, of secondary formation, detached from an adjacent mountain, and conveyed to the spot upon which it was found by some torrent or land-flood. In this opinion we might partially acquiesce, did not the artlessness of contemporary and concurring records militate against it, and had not the more accurate analysis of Vauquelin detected the same constituent parts as in the other stony and metalline substances denominated meteoric. "It is certainly composed of silica," observes this celebrated chemist, "of magnesia, of iron, of nickel, of sulphur, and of a small quantity of lime. Particular trials have convinced me of the presence of sulphur and nickel in the grains of malleable iron, and in the pyrites, though in different proportions. This stone, then, in every respect resembles others which have fallen from the atmosphere."

In the Commentary of Surius, a Carthusian monk of Cologne, mention is made of a shower of large stones which fell in Lombardy in 1510. These stones were harder than flint, and smelled of sulphur. The heaviest weighed 120 pounds. The same event is more particularly related by Cardan, in his work entitled *De Rerum Varietate* (lib. xiv. c. 72). According to this author, near the river Adda, not far from Milan, and at five o'clock in the evening, about 1120 stones fell from the air, one of them weighing 120 pounds, and another sixty pounds. Many were presented to the French governor and his deputy. At three o'clock in the afternoon the sky appeared as if in a general blaze; and the passage, though somewhat ambiguous, would lead us to infer that the meteor was visible for two hours. Like many of the learned and unlearned of his day, Cardan instantly connects the extraordinary appearance with the political transactions of his district.

We shall next produce an interesting extract from the memoirs of the Emperor Jehangire, written in Persian by himself, and translated by Colonel Kirkpatrick.

"*A. H.* 1030, *or* 16*th year of the reign*.—The following is amongst the extraordinary occurrences of this period. Early on the 30th of Furverdeen of the present year (1620), and in the eastern quarter of the heavens, there arose in one of the villages of the purgunnah of Jalindher such a great and tremendous noise, as had nearly, by its dreadful nature, deprived the inhabitants of the place of their senses. During this noise a luminous body was observed to fall from above on the earth, suggesting to the beholders the idea that the firmament was raining fire. In a short time, the noise having subsided, and the inhabitants having recovered from their alarm, a courier was despatched to Mahommed Syeed, the aumul of the aforesaid purgunnah, to advertise him of this event. The aumul, instantly mounting his horse, proceeded to the spot. Here he perceived the earth, to the extent of a dozen of yards in length and breadth, to be burned to such a degree, that not the least trace of verdure or a blade of grass remained, nor had the heat yet subsided entirely. Mahommed Syeed hereupon directed the aforesaid space of ground to be dug up, when the deeper it was dug the greater was the heat of it found to be. At length a lump of iron made its appearance, the heat of which was so violent that one might

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have supposed it to have been taken from a furnace. After some time it became cold, when the aumul conveyed it to his own habitation, from whence he afterwards despatched it in a sealed bag to court.

"Here I had this substance weighed in my presence. Its weight was 160 tolahs.[1] I committed it to a skilful artisan, with orders to make of it a sabre, a knife, and a dagger. The workman reported that the substance was not malleable, but shivered into pieces under the hammer. Upon this I ordered it to be mixed with other iron. Conformably to my orders, three parts of the *iron of lightning*[2] were mixed with one part of common iron, and from the mixture were made two sabres, one knife, and one dagger."

Our limits will not permit us to give the whole of the extract, nor the remarks of Mr Charles Greville and Colonel Kirkpatrick, which were read before the Royal Society of London on the 27th of January 1803. We feel no hesitation, however, in considering this document as something very nearly approaching to direct evidence of the fact in question.

The celebrated Gassendi informs us, that on the 27th of November 1627, about ten o'clock in the morning, during a very clear sky, he saw a flaming stone, of the apparent diameter of four feet, fall on Mount Vaision, an eminence situated between the small towns of Perne and Guillaumes, in Provence. This stone was surrounded by a luminous circle of different colours, nearly resembling the rainbow, and its fall was accompanied with a noise like the discharge of artillery. It weighed fifty-nine pounds, and its specific gravity was to that of common marble as fourteen to eleven. It was of a dark metallic colour, and extremely hard. Though it was not subjected to chemical analysis, and is not now to be found, the circumstances which have been stated by the philosopher are sufficiently minute to operate on the conviction of those who are willing to be convinced.

From a curious book printed at Paris in 1672, and now become very scarce, entitled "Conversations tireés de l'Académie de M. l'Abbe Bourdelot, contenant diverses Recherches et Observations Physiques, par le Sieur Legallois," we make the ensuing extract: "A member presents a fragment of two stones which fell near Verona, one of which weighed 300, and the other 200 pounds. These stones," says he, "fell during the night, when the weather was perfectly mild and serene. They seemed to be all on fire, and came from above, but in a slanting direction, and with a tremendous noise. This prodigy terribly alarmed three or four hundred eye-witnesses, who were at a loss what to think of it. These stones fell with such rapidity that they formed a ditch, in which, after the noise had ceased, the spectators ventured to approach them, and examine them more closely. They then sent them to Verona, where they were deposited in the academy, and that learned body sent fragments of them to different places." That which accompanied the above intimation was of a yellowish hue, very easily pulverized, and smelled strongly of sulphur. In the course of examining one of these stones, M. Laugier, professor of pharmacy at Paris, has recently detected the presence of chrome, by means of the caustic alkali. The date of the Verona phenomenon, if we have been correctly informed, is 1663.

In the Bornian collection there is a substance which is designated "Ferrum retractorium, granulis nitentibus matrice virescenti immixtis (*Ferrum virens*, Lin.), cujus fragmenta ab unius ad viginti usque librarum pondus, cortice nigro scoriaceo circumdata, ad Plann, prope Tabor, circuli Bechinensis Bohemiæ, passim reperiuntur." The following note is subjoined: "Quæ fragmenta, 3 Julii anni 1753, inter tonitrua, e cælo pluisse creduliores quidam asserunt." The expression "*creduliores quidam*," it may be alleged, at once destroys the evidence of this memorandum. It deserves, however, to be noted, that in regard to our present subject, what was formerly accounted the credulity of the vulgar, may now, upon several occasions, be construed into probability, if not into matter of fact; and that Mr Greville has found the identical fragment to have the same composition with the other meteoric stones. Hence we are compelled either to admit its super-terrestrial origin, or the existence of a substance originally belonging to the earth, and yet agreeing in character with those deemed atmospheric. The former branch of the alternative is perfectly consonant with well-authenticated facts; whereas, of the latter, we are not warranted to pronounce that a single case has hitherto been established to the perfect satisfaction of any chemist or mineralogist.

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But we have now to direct our attention to a report of M. de Lalande, inserted in the Historical Almanac of Bresse for 1756. In the month of September 1753, about one o'clock afternoon, when the weather was very hot, and very serene, without the least appearance of clouds, a very loud noise, like the discharge of two or three cannons, was heard within the circumference of six leagues, but was of very short duration. This noise was loudest in the neighbourhood of Pont-de-Vesle; and at Liponas, a village three leagues from the last-mentioned place, it was even accompanied with a hissing, like that of a cracker. On the same evening there were found at Liponas and at Pin two blackish masses, of a form nearly circular, but very uneven, which had fallen on ploughed ground, and sunk, by their own weight, to the depth of half a foot below the surface. One of them weighed about twenty pounds; and a fragment of one of them, weighing eleven and a half pounds, was preserved in the cabinet of M. Varenne de Beost, at Dijon. The basis of these masses resembled a grayish whinstone, and was very refractory; and some ferrugineous particles were disseminated in grains, filaments, or minute masses, throughout the substance of the stone, especially in its fissures. This iron, when subjected to a red heat, became obedient to the magnet. The black coating on the surface M. de Lalande ascribes to fusion, induced by violent heat. This gentleman's acknowledged respectability, and accuracy of observation, combined with the circumstances which he has produced, circumstances, too, which, if mis-stated, lay open to public investigation, powerfully plead in favour of his testimony.

On the 15th of September 1760, according to the Abbé Bachelay, about half past four o'clock afternoon, there appeared near the Chateau de Chevabrie, in the neighbourhood of Luce, a small town of the province of Maine, a stormy cloud, from which proceeded a loud peal of thunder, like the discharge of cannon, and followed by a noise which was mistaken by several people for the lowing of oxen. This sound was heard over a space of about two leagues and a half, but unaccompanied by any perceptible flame. The reapers in the parish of Perigué, about three leagues from Luce, on hearing the same noise, looked up, and saw an opake body, which described a curve, and fell on soft turf, upon the high road from Mons, near which they were at work. They all quickly ran up to it, and found a sort of stone, nearly half of which was buried in the earth, and the whole so hot that it could not be touched. At first they ran away in a panic; but upon returning to the spot some time afterwards, they found the stone precisely in the same situation, and sufficiently cooled to admit of being handled, and narrowly examined. It weighed seven ounces

[1] A tolah is about 180 grains Troy weight.

[2] This expression is equivalent to our term *thunderbolt*.

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and a half, and was of a triangular form, presenting, as it were, three rounded horns, one of which, at the moment of the fall, had entered into the ground, and was of a gray or ash colour, whilst the rest, which was exposed to the air, was very black. When the abbé presented this stone to the academy, that body appointed three of its number, namely, MM. Lavoisier, Fougeroux, and Cadet, to examine and analyse it. This task they performed with more care and accuracy than M. de Lalande had done on the preceding occasion; but their trial was confined to an integral part of the whole, considered as a homogeneous substance, instead of being repeated on each of the constituent parts. The substance was of a pale cinereous hue, speckled with an infinite number of small and shining metallic points, visible through a magnifying glass. That part of the outer surface which remained above ground was incrusted with a thin black coating, which seemed to have undergone fusion, and which gave a few sparks when struck with steel. The specific gravity of the mass was 3535. Two other stones, nearly of the same characters, the one reported to have fallen at Aire, in Artois, and the other in the Cotentin, in Normandy, were also presented to the academy in the course of the same year, by M. Gurson de Boyaval, honorary lieutenant-general of the bailliage of Aire, and the younger Morand. According to the academical report, these three stones, when compared, presented no difference to the eye; they were of the same colour, and nearly of the same grain, exhibiting metallic and pyritous particles, and covered with a black and ferrugineous incrustation. Although the coincidence of facts and circumstances, in three places so remote from one another, did not convince the academy that these stones had been conveyed to the earth by lightning, yet it induced them to invite naturalists to prosecute the examination of the subject.

On the 20th of November 1768, a stone fell at Mauerkircken, near the river Inn, in Bavaria, which weighed thirty-eight pounds, and was of a triangular form, being about eight inches in thickness. Its fall was accompanied by a hissing noise, and great darkness in the atmosphere. This meteorolite penetrated two feet and a half into the soil. Part of it, formerly in the cabinet of the Right Honourable Charles Greville, is now in the British Museum.

The next remarkable case that has been recorded occurred on the 20th of August 1789, at Barbotan, near Roquefort, in the landes of Bourdeaux, and is thus related by Citizen Lomet, who was known to several members of the Institute, and happened to be at Agen when the meteor appeared. "It was a very bright fire-ball, as luminous as the sun, of the size of an ordinary balloon, and, after inspiring the inhabitants with consternation, burst and disappeared. A few days afterwards, some peasants brought stones, which they said fell from the meteor; but the philosophers to whom they offered them laughed at their assertions as fabulous. The peasants would have now more reason to laugh at the philosophers." One of these stones broke through the roof of a cottage, and killed a herdsman and some cattle. Vauquelin, who received a *procès-verbal* of the circumstances, also examined one of the specimens.

A much more remarkable phenomenon, however, of the same description, occurred near Agen, on the 24th of July 1790. An inhabitant of St Severe communicated the following particulars to M. Darcet the chemist, who was then resident at Paris. "Our town's-people were yesterday very much alarmed. About a quarter past nine o'clock in the evening, there suddenly appeared in the atmosphere a fire-ball, dragging a long train, which diffused a very vivid light over the horizon. This meteor soon disappeared, and seemed to fall at one hundred paces from us. It was quickly followed by an explosion louder than that of a cannon or of thunder. Every body dreaded being buried under the ruins of his house, which seemed to give way from the concussion. The same phenomenon was seen, and the report heard, in the neighbouring towns, as Mont de Marsan, Tartas, and Dax. The weather in other respects was very calm, without a breath of wind or a cloud, and the moon shone in all her brightness." M. Darcet's brother, a clergyman in that part of the country, sent him a small stone, which was picked up on the morning after the explosion, and the history of which he was scrupulously anxious to investigate. Being satisfied with respect to all the particulars, he at length despatched it to Paris, accompanied with some very curious remarks. "When these stones fell," says he, "they had not their present degree of hardness. Some of them fell upon straw, bits of which stuck to the stones, and incorporated with them. I have seen one in this predicament. It is at present at La Bastide; but I cannot persuade the owner to part with it. Those which fell on the houses produced a noise, not like that of stones, but rather of a substance which had not yet acquired compactness."

M. Baudin mentions, that, as M. Carris of Barbotan and he were walking in the court of the Castle of Mormes, about half past nine o'clock in the evening of the 24th of July 1790, when the air was perfectly calm, and the sky cloudless, they found themselves suddenly surrounded by a pale clear light, which obscured that of the moon, although the latter was nearly full. On looking up, they observed, almost in their zenith, a fire-ball, of a larger apparent diameter than that of the moon, dragging a tail which seemed to be five or six times longer than the diameter of its body, and which gradually tapered to a point; the latter approaching to blood-red, though the rest of the meteor was of a pale white. This luminous body proceeded with great velocity from south to north, and in two seconds split into portions of considerable size, like the fragments of a bursting bomb. These fragments became extinguished in the air, and some of them, as they fell, assumed that deep-red colour which had been observed at the point of the tail. Two or three minutes afterwards, M. Baudin and his friend heard a dreadful explosion, like the simultaneous firing of several pieces of ordnance; but they were not sensible of any tremulous motion under their feet, although the concussion of the atmosphere shook the windows in their frames, and threw down kitchen utensils from their shelves. When these gentlemen removed to the garden, the noise still continued, and appeared to be directly over their heads. Some time after it had ceased, they heard a hollow sound rolling, in echoes, for about fifty miles, along the chain of the Pyrenees, and at the end of about four minutes gradually dying away in distance. At the same time, a strong sulphureous odour was diffused in the atmosphere. The interval which occurred between the disruption of the meteor and the loud report induced M. Baudin to conjecture that this fire-ball must have been at least eight miles from the earth's surface, and that it fell about four miles from Mormes. "The latter part of my conjecture," says he, "was soon confirmed by an account which we received of a great many stones having fallen from the atmosphere at Juillac and in the neighbourhood of Barbotan." It appears, indeed, from the concurring testimony of intelligent persons worthy of credit, that the meteor really exploded at a little distance from Juillac, and that its fragments were found lying in an almost circular space of nearly two miles in diameter. Some of them weighed eighteen or twenty, and a few, it is alleged, even fifty pounds. M. de Carris procured one of eighteen pounds, which he transmitted to the Academy of Sciences at Paris. That examined by M. Baudin was small, but heavy in proportion to its size, black on the outside, grayish within, and interspersed with many minute, shining, metallic particles.

In one of his letters to Professor St Amand, M. Goyon d'Arzas remarks, that these stones, though generally smooth

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on the outside, presented some longitudinal cracks or fissures, whilst their interior parts exhibited symptoms of metallic veins, especially of a ferrugineous complexion. When yet red hot, and scattered about in various directions, they formed that magnificent fire-work, that shower of flame, which enlightened the horizon over a large tract of country; for this extraordinary meteor was seen at Bayonne, Auch, Pau, Tarbes, and even at Bordeaux and Toulouse. At the last-mentioned place it excited but little attention, on account of its great distance, and its appearing only a little brighter than a shooting star. It, moreover, deserves to be noted, that the meteorolites in question were found upon a bare moor, of an extremely thin soil, on which no such stones, or indeed stones of any description, had been observed within the memory of man. They who are solicitous of additional information on this part of the subject may consult the *Journal des Sciences Utiles* of Montpellier for 1790, and the *Décade Philosophique* for February 1796.

Our chronological series of cases has now brought us to the fall of several meteorolites near Sienna, the particulars of which, as reported by the Earl of Bristol and Sir William Hamilton, are recorded in the first part of the Philosophical Transactions for the year 1795 (p. 103). Mr King, likewise, in the tract which we have already quoted, communicates some interesting circumstances relative to this phenomenon, chiefly extracted from an account of it published by Professor Soldani. Whilst we refer our readers to these details, we cannot omit mentioning here, that, in regard to aspect and composition, the Sienna stones are perfectly analogous to the others already noticed, and very different from any that occur in Tuscany. As the meteor from which they were discharged appeared on the morning after a violent eruption of Vesuvius, they were at first supposed to be volcanic, until cool reflection and examination betrayed the extravagance of such a hypothesis. The precise number of stones which were collected on this occasion is not specified; but many of them were small, weighing from a quarter of an ounce to two ounces. The date of the Sienna meteor is the 16th of June 1794. On the 13th of December in the following year, about three o'clock in the afternoon, another of these singular stones, weighing about fifty-six pounds, fell near the country-house of Captain Topham, in Yorkshire. The captain's report, which is inserted in the Gentleman's Magazine for 1796, is distinct and satisfactory; whilst the chemical examination of the mass, detailed in Mr Howard's paper in the Philosophical Transactions for 1802, affords a still more decisive proof of its atmospheric origin. M. de Drée also found it to correspond exactly in aspect and character with fragments of meteoric stones from Benares and Ville-Franche. The original mass is larger than a man's head.

Mr Southey, in his letters from Spain and Portugal, transcribes the authenticated relation of another instance of the descent of a stone from the clouds on the 19th of February 1796. But we pass to some of the most important details relative to the stone which is affirmed to have fallen near Ville-Franche, in the department of the Rhone, on the 12th of March 1798. When it was transmitted to Professor Sage, member of the National Institute, he considered it at first as only a pyritous and magnetical ore of iron, although it bore no resemblance to any known species of ore of that metal, inasmuch as it contained nickel, silica, magnesia, and native iron, which shone like steel when polished. "It is of an ash-gray colour," says M. Sage, "granulated, and speckled with gray, shining, and pyritous metallic points. One of its surfaces is covered with a dingy black enamel, about the third of a line in thickness. This stone acts very powerfully on the magnetic needle. When the senator Chasset transmitted it to me, it was accompanied with an historical notice of similar import with that of M. Delièvre of Ville-Franche, who saw and described the phenomenon on the spot." At six o'clock in the evening, a round body, which diffused the most vivid light, was observed in the vicinity of Ville-Franche, moving westward, and producing a hissing like that of a bomb which traverses the air. This luminous body, which was seen at the same time at Lyons and on Mont Cenis, marked its path by a red track of fire, and exploded, about two hundred toises from the earth, with a tremendous report and concussion. One of the flaming fragments fell on the vineyard of Peter Crépier, an inhabitant of Sales. On the spot where this portion of the meteor was seen to fall, and in a fresh opening of about twenty inches in depth and eighteen in width, was found a black mass, fifteen inches in diameter, and rounded on one side.

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An account of the same meteor was published in the *Journal de Physique* by M. de Drée. From his minute and deliberate investigation, it appears that the fire-ball had scarcely fixed the attention of the inhabitants of Sales and the adjacent villages, when its rapid approach, accompanied by a terrible whizzing noise, like that of an irregular hollow body, traversing the air with unusual velocity, inspired the whole commune with alarm, especially when they observed it passing over their heads, at an inconsiderable elevation. It left behind a long train of light, and emitted, with an almost unceasing crackling, small vivid flames, like little stars. Its fall was remarked, at the distance of only fifty paces, by three labourers, one of whom, named Montillard, let fall his coat and bundle of sticks, that he might run the faster; whilst the other two, Chardon and Lapoces, fled with equal precipitation to Sales, where the alarm had become general. These three witnesses attest the astonishing rapidity of the meteor's motion, and the hissing which proceeded from the spot where it fell. So terrified was Crépier at the explosion, that he locked himself up with his family, first in his cellar, and then in his private apartment; nor did he venture abroad till next morning, when, in the company of M. Blandel, Chardon, Lapoces, and many others, he repaired to the opening which had been made by the fire-ball. At the bottom of this opening, which was eighteen inches deep, including the entire thickness of the mould, they found a large black mass, of an irregularly ovoid form, having a fanciful resemblance to a calf's head. Although no longer hot, it smelled of gunpowder, and was cracked in several places. When the observers broke it, and discovered nothing but stone, indifference succeeded to curiosity, and they coolly ascribed its appearance to causes more or less whimsical and supernatural. The original weight of this stone was about twenty pounds. Its black vitrified surface gave fire with steel. Its interior was hard, earthy, ash-coloured, of a granular texture, presenting different substances scattered through it, namely, iron in grains, from the smallest size to a line or even more in diameter, somewhat malleable, but harder and whiter than forged iron; white pyrites, both lamellated and granular, and in colour approaching to nickel; some gray globules, which seemed to present the characters of trap; and a very few and small particles of steatites, inclining to an olive hue. On account of its heterogeneous composition, its specific gravity could not be easily ascertained. One hundred parts of the mass gave, according to M. Vauquelin, 46 of silica, 38 of oxide of iron, 15 of magnesia, 2 of nickel, and 2 of lime. The excess of this result was ascribed to the absorption of oxygen by the native iron during the process.

On the 19th of December 1798, about eight o'clock in the evening, the inhabitants of Benares and its neighbourhood observed in the heavens a very luminous meteor, in the form of a large ball of fire, which exploded with a loud noise, and from which a number of stones were precipitated near Krakhut, a village about fourteen miles from the city of Benares. Mr Davis, the judge and magistrate

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of the district, affirmed that in brilliancy it equalled the brightest moonlight. Both he and Mr Erskine, the assistant collector, were induced to send persons in whom they could confide to the spot where this shower of stones was asserted to have taken place, and thus obtained additional evidence of the phenomenon, and several of the stones, which had penetrated about six inches into fields recently watered. Mr Maclane, a gentleman who resided near Krakhut, presented Mr Howard with part of a stone, which had been brought to him the morning after its descent, by the watchman who was on duty at his house, and through the roof of whose hut it had passed, and buried itself several inches in the floor, which was of consolidated earth. Before it was broken, it must have weighed upwards of two pounds. At the time that this meteor appeared, the sky was perfectly serene; not the smallest vestige of a cloud had been seen since the 11th of the month, nor was any observed for many days afterwards. "Of these stones," says Mr Howard, "I have seen eight nearly perfect, besides parts of several others which had been broken by the possessors to distribute among their friends. The form of the more perfect ones appeared to be that of an irregular cube, rounded off at the edges; but the angles were to be observed on most of them. They were of various sizes, from about three to upwards of four inches in their largest diameter; one of them, measuring four inches and a quarter, weighed two pounds twelve ounces. In appearance they were exactly similar; externally they were covered with a hard black coat or incrustation, which in some parts had the appearance of varnish or bitumen; and on most of them were fractures, which, from their being covered with a matter similar to that of the coat, seemed to have been made in the fall by the stones striking against each other, and to have passed through some medium, probably an intense heat, previous to their reaching the earth. Internally they consisted of a number of small spherical bodies, of a slate colour, imbedded in a whitish gritty substance, interspersed with bright shining spiculæ, of a metallic or pyritical nature. The spherical bodies were much harder than the rest of the stone; the white gritty part readily crumbled on being rubbed with a hard body; and, on being broken, a quantity attached itself to the magnet, but more particularly the outside coat or crust, which appeared almost wholly attractable by it."

The history of the extraordinary shower of stones which fell near L'Aigle, in Normandy, on the 26th of April 1803, first appeared in the following artless letter, addressed by M. Marais, an inhabitant of the place, to his friend in Paris. "An astonishing miracle has just occurred in our district. Here it is, without alteration, addition, or diminution. It is certain that it is the truth itself. On Friday (26th of April), between one and two o'clock in the afternoon, we were roused by a murmuring noise like thunder. On going out we were surprised to see the sky pretty clear, with the exception of some small clouds. We took it for the noise of a carriage, or of fire in the neighbourhood. We were then in the meadow, to examine whence the noise proceeded, when we observed all the inhabitants of the Pont de Pierre at their windows, and in gardens, inquiring concerning a cloud which passed in the direction of from south to north, and from whence the noise issued, although that cloud presented nothing extraordinary in its appearance. But great was our astonishment when we learned that many and large stones had fallen from it, some of them weighing ten, eleven, and even seventeen pounds, in the space between the house of the Buat family (half a league to the north-north-east of L'Aigle) and Glos, passing by St Nicolas, St Pierre, &c. which struck us at first as a fable, but which was afterwards found to be true. The following is the explanation given of this extraordinary event by all who witnessed it. They heard a noise like that of a cannon, then a double report still louder than the preceding, followed by a rumbling noise, which lasted about ten minutes, the same which we also heard, accompanied with hissings, caused by these stones, which were counteracted in their fall by the different currents of air, which is very natural in the case of such a sudden expansion. Nothing more was heard; but it is remarkable, that, previously to the explosion, the domestic fowls were alarmed, and the cows bellowed in an unusual manner. All the country people were much dismayed, especially the women, who believed that the end of the world was at hand. A labourer at La Sapée fell prostrate on the ground, exclaiming. 'Good God, is it possible that thou canst make me perish thus? Pardon, I beseech thee, all the faults I have committed.' The most trifling objects, in fact, might create alarm; for it is not improbable that history offers no example of such a shower of stones as this. The piece which I send was detached from a large one, weighing about eleven pounds, which was found between the house of the Buats and Le Fertey. It is said that a collector of curiosities purchased one of seventeen pounds weight, that he might send it to Paris. Every body in this part of the country is desirous of possessing a whole stone, or a fragment of one, as an object of curiosity. The largest were darted with such violence that they entered at least a foot into the earth. They are black on the outside, and grayish, as you see, within, seeming to contain some species of metal and nitre. If you know before us of what ingredients they are composed, you will inform us. One fell near M. Bois de la Ville, who lives near Glos. He was much afraid, and took shelter under a tree. He has found a great number of them, of different sizes, in his court-yard, his wheat field, &c. without reckoning all those which the peasants have found elsewhere. Numberless stories, more or less absurd, have been circulated amongst the people. You know that our country is fertile in such tales. Cousin Moutardier sends one of these stones to Mademoiselle Hébert; and he is not less eager than we are to know how these substances can be compressed and petrified in the air. Do try to explain the process. The person who gave me the largest stone which I send to you went to take it at the moment that it fell, but it was so hot that it burned him. Several of his neighbours shared the same fate in attempting to lift it. The elder Buat has just arrived, and desires us to add, that a fire-ball was observed to hover over the meadow. Perhaps it was wildfire."

At the sitting of the Institute on the 9th of May, Fourcroy read a letter from L'Aigle addressed to M. Vauquelin, and which sufficiently corroborates the preceding statements. But we pass to the substance of M. Biot's letter addressed to the minister of the interior, and published in the *Journal des Débats*. This very eminent philosopher was deputed by government to repair to the spot, and collect all the authentic facts. He left Paris on the 5th of June, and, instead of proceeding directly to L'Aigle, went first to Alençon, which lies fifteen leagues to the west-south-west of that place. He was informed on his way that a globe of fire had been observed moving towards the north, and that its appearance was followed by a violent explosion. From Alençon he journeyed through various villages to L'Aigle, being directed in his progress by the accounts of the inhabitants, who had all heard the explosion on the day and at the hour specified. Almost all the inhabitants of twenty hamlets, scattered over an extent of upwards of two square leagues, affirmed that they were eye-witnesses of a dreadful shower of stones which were darted from the meteor. The following is his summary of the whole evidence. "On Tuesday, 6th Floreal, year 11, about one o'clock P. M. the weather being serene, there was observed from Caen, Pont d'Audemer, and the envi-

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rons of Alençon, Falaise, and Verneuil, a fiery globe, of a very brilliant splendour, and which moved in the atmosphere with great rapidity. Some moments after, there was heard at L'Aigle, and in the environs of that town, in the extent of more than thirty leagues in every direction, a violent explosion, which lasted five or six minutes. At first there were three or four reports, like those of cannon, followed by a kind of discharge which resembled the firing of musketry; after which there was heard a dreadful rumbling, like the beating of a drum. The air was calm, and the sky serene, except a few clouds, such as are frequently observed. This noise proceeded from a small cloud which had a rectangular form, the largest side being in a direction from east to west. It appeared motionless all the time that the phenomenon lasted; but the vapours of which it was composed were projected momentarily from different sides, by the effect of the successive explosions. This cloud was about half a league to the north-north-west of the town of L'Aigle. It was at a considerable elevation in the atmosphere, for the inhabitants of two hamlets, a league distant from each other, saw it at the same time above their heads. In the whole canton over which this cloud was suspended, there was heard a hissing noise like that of a stone discharged from a sling, and a great many mineral masses, exactly similar to those distinguished by the name of *meteoric stones*, were seen to fall. The district in which these masses were projected forms an elliptical extent of about two leagues and a half in length, and nearly one in breadth, the greatest dimension being in a direction from south-east to north-west, forming a declination of about 22 degrees. This direction, which the meteor must have followed, is exactly that of the magnetic meridian, which is a remarkable result. The greatest of these stones fell at the south-eastern extremity of the large axis of the ellipse, the middle-sized in the centre, and the smaller at the other extremity. Hence it appears that the largest fell first, as might naturally be supposed. The largest of all those that fell weighs seventeen pounds and a half. The smallest which I have seen weighs about two gros (a thousandth part of the last). The number of all those which fell is certainly above two or three thousand."

Any one who compares the various accounts of the L'Aigle meteor with a critical eye, may detect some apparent contradictions, which, however, on reflection, will be found to be strictly conformable to the truth. Thus, according to some, the meteor had a rapid motion, others believed it stationary; some saw a very luminous ball of fire, others only an ordinary cloud. Spectators, in fact, viewed it in different positions with respect to its direction. They who happened to be in its line of motion would see it stationary, for the same reason that we fancy a ship under full sail to be motionless when we are placed in its wake, or when we view it from the harbour to which it is approaching in a straight line. They, on the other hand, who had a side view of the meteor, would reckon its progress more rapid, in proportion as their position approached to a right angle with its line of passage. They, again, who saw it from behind, as the inhabitants of L'Aigle, would perceive only the cloud of vapour which it left in its train, and which, in the dark, would figure like a blazing tail, in the same manner as the smoke of a volcano appears black during the day and red at night. Lastly, they who were placed in front of the meteor would reckon it stationary, but brilliant and cloudless.

It deserves to be remarked, that the L'Aigle stones were very friable for some days after their descent, that they gradually acquired hardness, and that after they had lost the sulphureous odour on their surface, they still retained it in their substances, as was found by breaking them. Professor Sage submitted them to several comparative trials with those of Ville-Franche; and, though the L'Aigle specimens present some globules of the size of a small coriander seed, of a darker gray than the mass, and not attractable by the magnet, yet, in respect of granular texture and general aspect, the coincidence was so striking as to lead one to suppose that they were all parts of the same mass. The L'Aigle stones, according to M. Fourcroy, are generally irregular, polygonal, often cuboid, sometimes sub-cuneiform, and exceedingly various in their diameter and weight. They are all covered with a black gravelly crust, consisting of a fused matter, and filled with small agglutinated grains of iron. The greater part of them are broken at the corners, either by their shock against each other, or by falling upon hard bodies. The internal parts resemble those of all the stones analyzed by Messrs Howard and Vauquelin, being gray, a little varied in their shades, granulated, and as it were scaly, split in many parts, and filled with brilliant metallic points, exactly of the same aspect as those of other stones of a like description. The proportions of their constituent materials are stated as nearly 54 silex, 36 oxidated iron, 9 magnesia, 3 nickel, 2 sulphur, and 1 lime, the five per cent. of increase arising from the oxidation of the metals produced by the analysis.

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Of the two specimens which M. Biot presented to the celebrated Patrin, one was less compact, and of a lighter gray, than the other, and likewise exhibited small patches of a rust colour. When immersed in water, it gave out a hissing sound, like the humming of a fly which is held by one wing; and as it began to dry, it was observed to be marked by curvilineal and parallel layers. The more compact specimens, when moistened, presented no such appearances, but assumed the aspect of a gray porphyry, with a base of trap, mottled with small white spots, and speckled with metallic points.

That some of the relations to which we have referred are vague and unsatisfactory, cannot be denied; but the circumstantial testimony conveyed by others is pointed and positive; and the whole mass of historical proof, especially when combined with the argument deduced from the identity of the physical and chemical constitution of the stones, appears to us to be altogether irresistible.

In the course of our inquiry into this novel and interesting subject, we have ascertained a variety of circumstances which render it highly probable, if not indubitable, that those detached masses of native iron, the history of which has so often staggered and perplexed the geologist, are only modifications of meteoric depositions. The Tartars, for example, ascribe the descent of the Siberian mass described by Chladni, Pallas, Patrin, and others, to a period that is lost in the remoteness of antiquity; and whilst tradition thus favours our hypothesis, the analogy which is obviously observable, in point of texture and chemical characters, with those of other solid bodies the fall of which is no longer questioned, strengthens tradition. According to the discoveries of Proust and Klaproth, native iron, reputed meteoric, differs from that which occurs in a fossil state by the presence of nickel. The former of these celebrated analysts obtained fifty grains of sulphate of nickel from a hundred of the South American mass, and his results are corroborated by Mr Howard and the Count de Bournon.

Of the two pieces of Siberian iron possessed by Mr Greville, one, which was transmitted by Dr Pallas, weighs several pounds; and another presents a cellular and ramified texture, analogous to that of some very light and porous volcanic scoriæ. When attentively examined, there may be perceived in it not only empty cells, but also impressions or cavities of greater or less depth, and in some of which there remains a transparent substance, of a yellowish-green colour. The iron itself is very malleable, and may be easily cut with a knife, or flattened under the hammer. The specific gravity is 6487, which is obviously inferior to that of unforged iron that has undergone fusion, and may be

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partly owing to the oxidizement of the surface of the iron, and partly to the many minute cavities in its substance, which are often rendered visible by fracture, and which have their surface also oxidized. The fracture is shining and silvery, like that of white cast iron; but its grain is much smoother and finer, and it is much more malleable when cold. The heavier specimen is more solid and compact, exhibiting no cavities or pores, though its surface is ramified and cellular. So blended and incorporated is its compact part with the yellowish-green substance mentioned above, that if the whole of the latter could be subtracted, the remainder would consist of iron in the metallic state, and would display the same cellular appearance as the preceding specimen, or as the superficial portion of that now described. This stony part of the composition usually assumes the appearance of small nodules, generally of an irregular shape, but sometimes nearly globular, with a smooth, shining, and glassy surface. This substance, which is always more or less transparent, is hard enough to cut glass, but makes no impression upon quartz. It becomes electric by friction, is very refractory, and varies in specific gravity from 3263 to 3300. Of all substances hitherto known, it approaches most to the peridot, or Wernerian chrysolite, which yielded to M. Klaproth nearly the same results which this substance did to Mr Howard. In the mass of iron it is liable to decomposition, changing to an opake white, and crumbling into a gritty dry powder when lightly pressed or squeezed between the fingers. "I cannot help observing," says the Count de Bournon, "that there appears to exist a very interesting analogy between these transparent nodules and the globules I described as making part of the stones said to have fallen on the earth. This analogy, though not a very strong one, may lead us to suppose that the two substances are similar in their nature, but that the globules are less pure, and contain a greater quantity of iron."

Although our limits will not permit us to dwell with minuteness on the physical and chemical characters of meteorolites, we shall shortly state those which the Count de Bournon found to appertain to the specimens from Benares, and which may serve as no unfair standard of the aspect and composition of the others.

Like all of the same origin which were subjected to the count's examination, the Benares stones are covered over the whole extent of their surface with a thin crust, of a deep black colour, sprinkled over with small asperities, which make it feel somewhat like shagreen or fish skin. Their fracture exhibits a grayish colour, and a granulated texture, like that of coarse gritstone. By the help of a lens, they are perceived to be composed of four different substances. One of these occurs in great abundance, in the form of small bodies, some of which are perfectly globular; others rather elongated or elliptical, and all of various sizes, from that of a small pin's head to that of a pea, or nearly so. These small globules are usually gray, sometimes inclining much to brown, and always opake; they are easily broken in any direction, and have a conchoidal fracture, and a fine, smooth, compact grain, with a slight degree of lustre approaching to enamel; lastly, they can destroy the polish of glass without being able to cut it, and sparkle faintly when struck with steel. Another of these substances is martial pyrites, of an indeterminate form, and reddish-yellow colour, slightly verging to the nickel tint, or to that of artificial pyrites; of a somewhat loosely granulated texture, and irregularly distinguished in the mass, being black when reduced to powder, and not attracted by the magnet. The third of these substances consists of small particles of iron, in a perfectly metallic state, so that they may be easily flattened or extended under the hammer; and, though in a much smaller proportion than the pyrites just mentioned, they impart the magnetic attraction to the stone. When a piece of the latter was pulverized, and the particles of iron separated from it as accurately as possible, by means of a magnet, they appeared to compose about two hundred parts of the weight of the stone. These three substances are united by means of a fourth, which is nearly of an earthy consistency, and of a whitish-gray colour. The black crust, or outward coating, though of very inconsiderable thickness, emits bright sparks when struck with steel, may be broken by the hammer, and seems to possess the same properties with the black oxide of iron, although, like the substance of the stone, it is occasionally intermixed with small particles of iron in the metallic state. These are easily distinguished by passing a file over the crust, which reveals their lustre. The specific gravity of the Benares stone is 3352. None of them, when breathed on, emit the argillaceous odour.

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In consequence of various experiments, M. Sage infers that meteorolites are composed of native iron, sulphuret of nickel, quartz or silica, alumina, and magnesia; that the proportions of iron and nickel vary; that the quartz seems to form at least one half of the stone, the alumina and magnesia the sixth, and the sulphur the thirtieth part. These general results pretty nearly accord with the more special reports of Howard and Vauquelin, except that the latter makes no mention of alumina, the existence of which in atmospherical stones is by no means distinctly ascertained.

We shall only beg leave to add, on this part of our subject, that Laugier, an ingenious chemist, by employing the caustic alkali, has detected a small portion of chrome. The results of his experiments, which are stated in the fifty-eighth volume of the *Annales de Chimie*, are, first, that the five stones from Verona, Barbotan, Ensisheim, L'Aigle, and the neighbourhood of Apt, besides the principles already recognised, contain about one per cent. of chrome; secondly, that it is exceedingly probable that all meteorolites contain this principle, since they all resemble one another in their physical and chemical properties, and have all, apparently, the same origin; and, thirdly, that in many cases the perfection of chemical analysis requires that the same substance should be treated both by acids and alkalies, since experience has shown, that a principle which eluded the former method has been revealed by the latter.

Having now, as we apprehend, sufficiently established the existence and nature of meteorolites, we hope that our readers will excuse us from enlarging on the various causes which have been assigned for their origin, as these seem to lie beyond the reach of our present state of knowledge. After a candid and patient review of the principal theories, we conceive that most of them are open to many and formidable objections.

The terrestrial hypotheses, we believe, begin already to be generally abandoned as untenable. Until the phenomenon of exploding meteors had been distinctly observed and recorded, Lemery and others could maintain, with some degree of plausibility, that lightning might tear up the ground, and convert soil into a compact mass. But the appearances of a thunder-storm and of a fire-ball are now ascertained to differ in various important particulars. Spectators worthy of credit have seen the latter terminate in the fall of solid bodies, and the composition of these solid bodies has been found to differ from that of all the known fossil substances on the surface of the globe. It is in vain, then, to allege that they are formed on the ground by common lightning, which has often produced very extraordinary effects, but which never generated thousands of stones in fine calm weather. The supposition that such stones have been projected from some of our volcanoes is hardly less conceivable. The ashes which accompany a violent eruption of Ætna or Vesuvius have, from their le-

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vity, been carried to a very considerable distance; but we are totally unacquainted with any projectile force which could dart solid masses many hundred miles through such a dense medium as the atmosphere. The compact lavas of burning mountains are never found remote from the scene of their formation, and none of them present the characters and aspect of the stones which we have described. M. Bory de St Vincent, indeed, in his *Voyage dans les quatre Principales Isles des Mers d'Afrique*, expounds a doctrine which, in our opinion, carries its confutation along with it. According to this writer, meteorolites were projected from immense depths, in an early stage of the earth's existence, when ignivomous mountains were endued with propelling forces sufficient to drive masses of matter into the regions of space, where they were constrained to obey, for ages, the combined laws of impulse and gravitation, until, in the progress of time, their spiral revolutions at length terminated upon the surface of their native earth.

Of those who contend for the *atmospherical* formation of meteorolites, scarcely any two agree in regard to the manner in which such formation is effected. Patrin, who is solicitous to extend and illustrate his theory of volcanoes, labours at great length to maintain the existence of a regular circulation of gaseous fluids between the primitive schistose strata of the globe and its surrounding atmosphere, and, from this fancied circulation, which he flatters himself he has *demonstrated*, he deduces the occasional ignition and concretion of portions of these fluids in the higher regions of the air. This ingenious mineralogist and geologist is so extremely tenacious of these ideas that we shall not attempt to disturb his self-complacency; but he will excuse us if we refuse to assent to results which rest upon imaginary foundations. The celebrated Muschenbroeck, in one part of his writings, ascribes the descent of stones from the air to earthquakes and volcanic eruptions, an opinion which later observations have disproved. In other passages, however, he seems to incline to a modification of the atmospherical hypothesis, and endeavours to trace the origin of shooting stars to an accumulation of the volatile matters which are suspended in the air. It is extremely probable, that shooting stars and fiery meteors have an intimate relation to one another, if they are not identical appearances; but it is certain that the former move at a much greater distance from our earth than fire-balls, and only occasion a transient luminous appearance in their passage through the upper regions of the atmosphere. Perhaps they are analogous to those telescopic sparks of light which were observed by M. Schröter. Muschenbroeck, however, adopts the vulgar notion of their falling to the earth, and seems to confound their residue with *tremella nostoc*. M. Salverte has given extension to the theory of formation from vapours, by having recourse to the agency of hydrogen gas. According to him, in consequence of the decomposition of water, which is constantly going on at the surface of the earth, immense quantities of hydrogen gas are continually rising into the atmosphere, and ascending to its higher regions. As this gas is capable of dissolving metals, it carries along with it a portion of iron and nickel. During thunder-storms this gas is kindled by electricity; the metals are deposited, reduced, melted, and vitrified; in other words, meteors are produced and stones formed. But this hypothesis is scarcely more satisfactory than the others. It does not account for the presence of magnesia and silica, nor does it explain why the stones are always composed of the same materials. Besides, the existence of hydrogen gas in the atmosphere has not been proved, far less that it forms a separate atmosphere, which is contrary to all experience; and it is well known, that a little hydrogen, mixed with a large portion of atmospheric air, cannot be fired by electricity. In general, we may observe, that if the origin of meteorolites be really atmospherical, the matters of which they are composed must have existed in one of two states, namely, in very attenuated particles or concretions of the matters themselves volatilized and held in solution in the air, or only in the *elements* of these matters. In the first case, when abandoned by their menstruum to their reciprocal tendencies, they would unite by aggregation only; in the second, by chemical combination. Now we can hardly suppose that disengagement of light and violent detonation should result from the mere affinity of aggregation, whereas they are strictly symptomatic of the affinity of composition. This, and various other considerations which might be stated, if we could make room for them, induce us to regard the doctrine of combination as the most plausible. M. Izarn, who has published a treatise on Atmospherical Lithology, has entered into a tedious and somewhat obscure exposition of his own theory, founded on this principle. We shall give the summary, as nearly as we can, in his own words.

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"Gaseous substances, arranged in spherical masses in the upper regions of the air, being admitted, the various agitations of the atmosphere should naturally waft some of these masses from their insulating medium, into one capable of combining with them. If the combination begins, the disengagement of light is explained. In proportion as the combination advances, the specific gravities are changed; and, consequently, a change of place will commence, and that in the quarter which presents least resistance, or where the medium is most rarefied, in course rather towards the south than the north. Hence, most fire-balls are observed to move from north to south, or from north-east to south-west. Motion being once impressed, the mass traverses other media, capable of supplying new principles, which, still increasing the weight, determine the curve; and when at length the principles which are at work, and which issue in all directions, have attained the requisite proportion for extinguishing the elements in the birth of the compound, the grand operation is announced by the explosion, and the product takes its place among the solids." That the stones in question are produced by chemical combination in the higher regions of the atmosphere, and that they are thus formed from their own elements, are suppositions fully as probable as any that have been advanced on the subject; but whether the union of their parts be effected in the manner detailed by M. Izarn we are unable to determine, both because we are uncertain if we perfectly comprehend his meaning, and because our range of data is as yet too circumscribed to warrant any specific or decisive conclusions.

A much bolder theory has been suggested, and its *possibility* demonstrated, by Laplace, who shows that meteorolites may be the products of lunar volcanoes. We shall present the reasoning upon which this extraordinary hypothesis is founded, in the popular and perspicuous language of Dr Hutton of Woolwich. The respect due to the name of Laplace will justify the length of the extract. "As the attraction of gravitation extends through the whole planetary system, a body placed at the surface of the moon is affected chiefly by two forces, one drawing it toward the centre of the earth, and another drawing it toward that of the moon. The latter of these forces, however, near the moon's surface, is incomparably the greater. But as we recede from the moon, and approach toward the earth, this force decreases, whilst the other augments; till at last a point of station is found between the two planets, where these forces are exactly equal, so that a body placed there must remain at rest; but if it be removed still nearer to the earth, then this planet would have the superior attraction, and the body must fall towards it. If a body, then, be projected from the moon towards the earth, with a force

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sufficient to carry it beyond the point of equal attraction, it must necessarily fall on the earth. Such, then, is the idea of the manner in which the bodies must be made to pass from the moon to the earth, if that can be done, the *possibility* of which is now necessary to be considered. Now, supposing a mass to be projected from the moon, in a direct line towards the earth, by a volcano, or by the production of steam by subterranean heat; and supposing, for the present, these two planets to remain at rest; then it has been demonstrated, on the Newtonian estimation of the moon's mass, that a force projecting the body with a velocity of 12,000 feet in a second would be sufficient to carry it beyond the point of equal attraction. But this estimate of the moon's mass is now allowed to be much above the truth; and, on M. Laplace's calculation, it appears that a force of little more than half the above power would be sufficient to produce the effect, that is, a force capable of projecting a body with a velocity of less than a mile and a half per second. But we have known cannon balls projected by the force of gunpowder with a velocity of 2500 feet per second or upwards, that is, about half a mile. It follows, therefore, that a projectile force, communicating a velocity about three times that of a cannon ball, would be sufficient to throw the body from the moon beyond the point of equal attraction, and cause it to reach the earth. Now there can be little doubt that a force equal to that is exerted by volcanoes on the earth, as well as by the production of steam by subterranean heat, when we consider the huge masses of rock, so many times larger than cannon balls, thrown on such occasions to heights also so much greater. We may easily imagine, too, such cause of motion to exist in the moon as well as in the earth, and that in a superior degree, if we may judge from the supposed symptoms of volcanoes recently observed in the moon by the powerful tubes of Dr Herschel; and still more, if we consider that all projections from the earth suffer an enormous resistance and diminution by the dense atmosphere of this planet, whilst it has been rendered probable, from optical considerations, that the moon has little or no atmosphere at all, to give any such resistance to projectiles.

"Thus, then, we are fully authorized in concluding, that the case of *possibility* is completely made out; that a known power exists in nature, capable of producing the foregoing effect, of detaching a mass of matter from the moon, and transferring it to the earth in the form of a flaming meteor or burning stone: at the same time we are utterly ignorant of any other process in nature by which the same phenomenon can be produced. Having thus discovered a way in which it is possible to produce those appearances, we shall now endeavour to show, from all the concomitant circumstances, that these accord exceedingly well with the natural effects of the supposed cause, and thence give it a very high degree of *probability*.

"This important desideratum will perhaps be best attained by examining the consequences of a substance supposed to be projected by a volcano from the moon into the sphere of the earth's superior attraction, and then comparing those with the known and visible phenomena of the blazing meteors or burning stones that fall through the air on the earth. And if in this comparison a striking coincidence or resemblance shall always or mostly be found, it will be difficult for the human mind to resist the persuasion that the assumed cause involves a degree of probability but little short of certainty itself. Now the chief phenomena attending these blazing meteors or burning stones are these: 1. That they appear or blaze out suddenly; 2. that they move with a surprisingly rapid motion, nearly horizontal, but a little inclined downwards; 3. that they move in several different directions with respect to the points of the compass; 4. that in their flight they yield a loud whizzing sound; 5. that they commonly burst with a violent explosion and report; 6. that they fall on the earth with great force, in a sloping direction; 7. that they are very hot at first, remain hot a considerable time, and exhibit visible tokens of fusion on their surface; 8. that the fallen stony masses have all the same external appearance and contexture, as well as internally the same nature and composition; and, 9. that they are totally different from all our terrestrial bodies, both natural and artificial.

"Now these phenomena we shall proceed to compare with the circumstances of a substance projected by a lunar volcano, and in the order in which they are here enumerated. And, first, with respect to the leading circumstance, that of a sudden blazing meteoric appearance, which is not that of a small bright spark, first seen at an immense distance, and then gradually increasing with the diminution of its distance. And this circumstance appears very naturally to result from the assumed cause. For, the body being projected from a lunar volcano, may well be supposed in an ignited state, like inflamed matter thrown up by our terrestrial volcanoes, which, passing through the comparatively vacuum in the space between the moon and the earth's sensible atmosphere, it will probably enter the superior parts of this atmosphere with but little diminution of its original heat; from which circumstance, united with that of its violent motion, this being ten or twelve times that of a cannon ball, and through a part of the atmosphere probably consisting chiefly of the inflammable gas rising from the earth to the top of the atmosphere, the body may well be supposed to be suddenly inflamed, as the natural effect of these circumstances; indeed it would be surprising if it did not. From whence it appears, that the sudden inflammation of the body, on entering the earth's atmosphere, is exactly what might be expected to happen.

"2. To trace the body through the earth's atmosphere, we are to observe that it enters the top of it with the great velocity acquired by descending from the point of equal attraction, which is such as would carry the body to the earth's surface in a very few additional seconds of time if it met with no obstruction. But, as it enters deeper in the atmosphere, it meets with still more and more resistance from the increasing density of the air, by which the great velocity of six miles per second must soon be greatly reduced to one that will be uniform, and only a small part of its former great velocity. This remaining part of its motion will be various in different bodies, being more or less as the body is larger or smaller, and as it is more or less specifically heavy; but, for a particular instance, if the body were a globe of twelve inches diameter, and of the same gravity as the atmospheric stones, the motion would decrease so as to be little more than a quarter of a mile per second of perpendicular descent. Now, whilst the body is thus descending, the earth itself is affected by a twofold motion, both the diurnal and the annual one, with both of which the descent of the body is to be compounded. The earth's motion of rotation at the equator is about seventeen miles in a minute, or two sevenths of a mile in a second; but in the middle latitudes of Europe little more than the half of that, or little above half a quarter of a mile, in a second; and if we compound this motion with that of the descending body, as in mechanics, this may cause the body to appear to descend obliquely, though but a little, the motion being nearer the perpendicular than the horizontal direction. But the other motion of the earth, or that in its annual course, is about twenty miles in a second, which is eighty times greater than the perpendicular descent in the instance above mentioned; so that, if this motion be compounded with the descending one of the body, it must necessarily give it the appearance of a very rapid motion in a direction nearly parallel to the horizon, but a little declining downwards; a circumstance

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which exactly agrees with the appearances of these meteoric bodies, as stated in the second article of the enumerated phenomena.

"3. Again, with regard to the apparent direction of the body; this will evidently be various, being that compounded of the body's descent and the direction of the earth's annual motion at the time of the fall, which is itself various in the different seasons of the year, according to the direction of the several points of the ecliptic to the earth's meridian or axis. Usually, however, from the great excess of the earth's motion above that of the falling body, the direction of this must appear to be nearly opposite to that of the former. And, in fact, this exactly agrees with a remark made by Dr Halley, in his account of the meteors in his paper above given, where he says that the direction of the meteor's motion was exactly opposite to that of the earth in her orbit. And if this shall generally be found to be the case, it will prove a powerful confirmation of this theory of the lunar substances. Unfortunately, however, the observations on this point are very few, and mostly inaccurate; the angle or direction of the fallen stones has not been recorded; and that of the flying meteor commonly mistaken, all the various observers giving it a different course, some even directly the reverse of others. In future, it will be very advisable that the observers of fallen stones observe and record the direction or bearing of the perforation made by the body in the earth, which will give us perhaps the course of the path nearer than any other observation.

"4. In the flight of these meteoric stones, it is commonly observed that they yield a loud whizzing sound. Indeed it would be surprising if they did not. For if the like sound be given by the smooth and regularly-formed cannon ball, and heard at a considerable distance, how exceedingly great must be that of a body so much larger, which is of an irregular form and surface, too, and striking the air with fifty or a hundred times the velocity.

"5. That they commonly burst and fly in pieces in their rapid flight, is a circumstance exceedingly likely to happen, both from the violent state of fusion on their surface, and from the extreme rapidity of their motion through the air. If a grinding-stone, from its quick rotation, be sometimes burst, and fly in pieces, and if the same thing happen to cannon balls when made of stone and discharged with considerable velocity, merely by the friction and resistance of the air, how much more is the same to be expected to happen to the atmospheric stones, moving with more than fifty times the velocity, and when their surface may well be supposed to be partly loosened or dissolved by the extremity of the heat there.

"6. That the stones strike the ground with a great force, and penetrate to a considerable depth, as is usually observed, is a circumstance only to be expected from the extreme rapidity of their motion and their great weight, when we consider that a cannon ball or a mortar shell will often bury itself many inches, or even some feet, in the earth.

"7. That these stones, when soon sought after and found, are hot, and exhibit the marks of recent fusion, are also the natural consequences of the extreme degree of inflammation in which their surface had been put during their flight through the air.

"8. That these stony masses have all the same external appearance and contexture, as well as internally the same nature and composition, are circumstances that strongly point out an identity of origin, whatever may be the cause to which they owe so generally uniform a conformation. And when it is considered,

"9. That in those respects they differ totally from all terrestrial compositions hitherto known or discovered, they lead the mind strongly to ascribe them to some other origin than the earth we inhabit; and none so likely as coming from our neighbouring planet.

"Upon the whole, then," continues Dr Hutton, "it appears highly probable that the flaming meteors and the burning stones that fall on the earth are one and the same thing. It also appears impossible, or in the extremest degree improbable, to ascribe these either to a formation in the superior parts of the atmosphere, or to the eruptions of terrestrial volcanoes, or to the generation by lightning striking the earth. But, on the other hand, that it is possible for such masses to be projected from the moon so as to reach the earth, and that all the phenomena of these meteors or falling stones, having a surprising conformity with the circumstances of masses that may be expelled from the moon by natural causes, unite in forming a body of strong evidence that this is in all probability actually the case."

M. Poisson, a very ingenious French mathematician, has shown, by an algebraical calculation, the possibility of a projectile reaching our planet from the moon. His calculation, however, which may be found in the work of Izarn, quoted above, proceeds on the supposition that our satellite has no atmosphere, or next to none. There are, no doubt, appearances which seem to favour this supposition, but they do not amount to positive proof of the fact. Even could the latter be established, the combustion of a volcano without the presence of atmospherical air would remain to be explained. But, granting that this difficulty were surmounted, there are other circumstances which we cannot easily reconcile to the lunar hypothesis. The occasional arrival of fragments of lava upon the earth's surface would argue, on a fair computation of chances, such a copious discharge of volcanic matters, that the moon, by this time, would consist of hardly any thing else. Again, if we may be allowed to reason from analogy, the volcanic productions of the moon should exhibit varieties of aspect and composition like those with which we are acquainted, and not a definite and precise number of the same ingredients. We may also remark, that the soft and incoherent state of several of the recent specimens of meteorolites but ill accord with their supposed passage through any considerable portion of space; and that the L'Aigle phenomenon, which is so distinctly recorded, evidently suggests the notion of instantaneous formation in the atmosphere. And though this view of the subject may be regarded by some as inexplicable, we cannot conceive that it is more so than the doctrine of crystallization, or than many of the results of chemical combination, the existence of which it is impossible to deny. These and other arguments may, we apprehend, be fairly urged against any theory which attempts to explain the history of meteors by the agency of lunar volcanoes.

The hypothesis of Dr Chladni, which likewise boasts of its advocates, though still more startling than the preceding, deserves to be stated. As earthy, metallic, and other particles, form the principal component parts of our planet, amongst which iron is the prevailing part, other planetary bodies, he affirms, may consist of similar, or perhaps the same component parts, though combined and modified in a very different manner. There may also be dense matters accumulated in smaller masses, without being in immediate connection with the larger planetary bodies, dispersed throughout infinite space, and which being impelled either by some projecting power or attraction, continue to move until they approach the earth or some other body, when, being overcome by attractive force, they immediately fall down. By their exceeding great velocity, which is increased by the attraction of the earth and the violent friction in the atmosphere, a strong electricity and heat must necessarily be excited, by which means they are reduced to a flaming and melted condition, and great quantities of vapour and different kinds of gases are thus disengaged, which distend the liquid mass to a monstrous size, until, by

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still further expansion of these elastic fluids, they must at length displode. That portions of cosmical matter are allowed to revolve in space, and to terminate their career on the surface of a planet, is a position too gratuitous and vague to be readily admitted, but the belief of which involves no principle of atheism or impiety, as some of Dr Chladni's antagonists have very unhandsomely insinuated. If worlds disappear, and others spring into existence, a sportive imagination may be permitted to indulge in the innocent supposition that fragments of their materials are detached from their fractured masses, and obey those laws of attraction which seem to extend their influence to the remotest corners of the universe.

For further information on the subject of this article, see Izarn's *Lithologie Atmosphérique;* Biot's *Relation d'un Voyage fait dans le Departement de l'Orne, pour constater la réalité d'un Météore observé à L'Aigle;* Böttiger's *Observations on the Accounts given by Ancient Authors, of Stones said to have fallen from the Clouds;* Fulda's *Memoir on Fire-Balls;* Cavallo's *Elements of Natural Philosophy;* Klaproth *on Meteoric Stones;* Soldani's *Account of the Tuscan Meteor;* Chladni's *Treatise on the Siberian Mass of Iron;* Mr Edward King's *Remarks concerning Stones said to have fallen from the Clouds;* and the *Transactions* of several learned societies. (I. I. I. I.)

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METEOROLOGY,

From *μετεωρος, sublimis,* is that science which describes and explains the various phenomena which occur in the region of our atmosphere. It has deeply engaged the attention of men in every state of society, from the roving savage to the refined votary of wealth and pleasure. The moment we cross our doors, we commit ourselves to the influence of the weather. But the hardier classes of the community, the shepherd, the ploughman, and the mariner, whose labour creates or procures the staple articles of life, are always exposed, by their occupation, to the mercy of the elements. They were hence led, by the strongest motives, to examine closely the varying appearance of the sky, and to distinguish certain minute alterations which commonly precede the more important changes. No doubt they would often mistake the indications of those aspects, and would infer conclusions from mere casual circumstances. Those tokens which portend the more violent convulsions of the atmosphere, the pelting storm or the careering tempest, are generally of a decided character; but the symptoms which go before the ordinary fluctuations of the weather can only be dimly conjectured by long experience and sagacious observation. This shadowy knowledge, this dubious and very limited anticipation of the changes which arrive in the medium we breathe, is merely the fruit of personal assiduity and application. Like the conclusions which men of discernment form to themselves on the subject of physiognomy, it is scarcely communicable; it receives therefore no accessions in the progress of ages, but perishes with the individual.

Origin of the science.

The vague rules which experience had formed on the subject of atmospheric changes were adopted by the philosophers of antiquity, and incorporated into their cosmological systems. But in attempting to explain the phenomena, they sought merely to satisfy the imagination; and the supposition of certain elements, each endued with peculiar properties, appeared, on a superficial view, to connect harmoniously the general facts.

In the infancy of science, however, it was very difficult to distinguish between such appearances as are only incidental, and those constant presages which invariably anticipate their effects. The different fluctuations that happen in the lower atmosphere seemed dependent on the influence of the heavenly bodies, which are continually altering their places. Not only the sun and moon appeared to rule the seasons, but the planets, and even the fixed stars, were conceived to retard or accelerate, by their feeble action, the revolution of the grand cycle of changes. The application of the term *aspect* to the positions of those remote bodies, implied a principle of intelligence, and the *stellar influence* shed by them might therefore be deemed capable of producing all the variety of effects. Hence the origin of *Physical Astrology*, which has, during so many ages, maintained ascendency in the world, and still colours the verses of our poets, and pervades the creed of the vulgar.

Influence of light.

The heat evolved by the luminous particles transmitted from the sun, as they lose themselves among the lower strata of our atmosphere, or under the surface of the land and the sea, varying in its intensity, according to the obliquity of their incidence, and the extent of medium which they traverse, produces the most important effects in the great economy of the globe. But the correct knowledge we have at length acquired concerning the mutual action of bodies, contracts the limits of the supposed celestial influence almost to a point. The light of the moon does not amount to the 100,000th part of that of the sun, and the heat which this very feeble illumination excites or communicates has never been detected by the most delicate instruments, or the best-devised experiments. But all the rays shot from the planets, and from the whole constellations of fixed stars, are quite lost in the contrast with those lunar beams. Their combined impressions, during the lapse of countless ages, on the atmospheric temperature, would hence elude the utmost powers of calculation.

Tides of the atmosphere.

It is only by their attractive force that the heavenly bodies, except the warming energy of the sun, can ever affect the constitution of this globe. As, by their action unequally exerted over its surface, they raise tides in the ocean, so they must likewise agitate the atmosphere with a corresponding reciprocation. This effect, however, depends much more on the proximity of the disturbing body, than on its magnitude or density. Thus the sun, with twenty-three million times the mass of the moon, yet being about four hundred times more distant, has only about the third part of her influence in causing the tides. But, according to the computations of Laplace, the joint action of the sun and moon is only capable of producing a tropical wind, flowing westward at the rate of about four miles a day; a quantity evidently too small to be ever subjected to observation, and certainly insufficient to occasion any immediate and practical results.

It may be calculated that Jupiter and Venus, in those parts of their orbits which approach the nearest to the earth, affect the aërial tides by a force 76,000 and 82,000 times less than the sun. Those planets could therefore excite a most minute shifting in the atmosphere, limited to a foot in the space of fourteen or fifteen days, or about a single mile in twenty years. As the mass of Mars is unknown, its disturbing force cannot be estimated, though it is less than that of Jupiter. But the combined influence of all the rest of the solar system is, from their great distance, incomparably smaller.

Inefficacy of the stellar influence.

Nothing can be so utterly groundless, therefore, as the disposition to refer the ordinary changes of the weather to the influence of the moon. But, compared with this, the fancied efficacy of the stellar aspects, which was for ages

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firmly believed by the learned world, vanishes into the shadow of a vision. Nor has the most elaborate examination of numerous registers of the weather disclosed any precise and constant connection between the phases of the moon or the positions of the stars, and the succession of atmospherical phenomena. The inferences which seem to indicate a different conclusion may be fairly disregarded, as drawn only from a loose and imperfect inspection of facts.

Cycles of the weather.

It cannot be disputed, however, that all the changes which happen in the mass of our atmosphere, involved, capricious, and irregular as they may appear, are yet the necessary results of principles as fixed, and perhaps as simple, as those which direct the revolutions of the solar system. Could we unravel the intricate maze, we might trace the action of each distinct cause, and hence deduce the ultimate effects arising from their combined operation. With the possession of such data, we might safely predict the state of the weather at any future period, as we now calculate an eclipse of the sun or moon, or foretell a conjunction of the planets. After the protracted chain of combinations has been completed, the same series of events must again be repeated through the boundless lapse of ages. As all the anomalies of the planets are periodical, so likewise the successive varieties follow some cycle of vast extent. In the remotest annals of atmospherical phenomena, we might descry a gleam of futurity, and read the changes which still lie hid in the womb of time.

But, besides this great cycle, there probably are much shorter interior and subordinate periods, in which the weather nearly, though not absolutely, returns after the same order. Whatever principles concur to modify its succession, the revolutions of the sun and moon are certainly the primary and predominant causes. The character of the weather is accordingly strongly marked by the vicissitudes of day and night, and by the annual repetition of summer and winter. The menstrual action of the moon escapes correct observation; but, accumulated during a sufficient time, it may possibly produce a decided influence. Every nineteen years the motions of the moon come to coincide with those of the sun, and her nodes perform their revolutions in nearly the same time, or about eighteen years. This period, or the half of it, has therefore not improbably some slight connection with the usual series of the changes of the weather.

"If the sages of antiquity be justly blamed for adopting implicitly the notions and prejudices of the vulgar, those of modern times may be charged with too eager a disposition to reject whatever savours of popular opinion. A collection of the numerous rules and remarks formed in the course of ages among different orders of men, deeply interested by their occupations in watching the changes of the sky, would undoubtedly contain some important truths, which the diligence and sagacity of the philosopher might discriminate, and employ for the basis of beneficial speculations. The most sanguine can hardly uphold the prospect that mankind will ever arrive at such a pitch of knowledge as to be capable of prognosticating the future modifications of the atmosphere, with the same precision with which they can foretell the successive revolutions of the heavenly bodies; yet the motions, however irregular in appearance, which prevail in the element that we breathe, are, equally with those performed in the regions of space, the result of certain fixed laws. The variable aspect of the sky proceeds partly from the direct action of the sunbeams, but principally from the winds which they excite and maintain. The unequal gravitation of the different portions of our atmosphere to the sun, and to the moon especially, must occasion some small effect in producing or altering the aërial currents; and even the disturbing forces of the planets have a remote share, how minute soever, in the formation of meteors. Nor can we hesitate to conclude, with the late ingenious and elegant M. Bailly, whose fate demands the tribute of a tear, that the notions, so widely spread among men, of the aspects and influences of the celestial bodies, are only the corrupted remains of astronomical science, already advanced to high perfection in some distant age of the world. If motions were to rise and cease instantaneously with the operation of their causes, the same succession of seasons would exactly attend on each revolution of the sun; but the currents of air acquire velocity by degrees, and thenceforth continue to flow till their force is spent. The varied face of our terraqueous globe will, therefore, modify the direction, the power, and the duration of the winds, raised by the action of the solar rays. Hence an extreme complication of causes, which will produce an immense series of fluctuating events. That profound geometer M. de Lagrange has established by demonstration, that all the changes arising from the disturbing forces in the planetary system are subjected to certain vast cycles, on the return of which the same motions are perpetually renewed. Similar periods, but of an extent that affrights the imagination, probably regulate the modifications of the atmosphere; for, whenever a coincidence of circumstances prevails, the series of appearances must inevitably recur. The aggregate labours, indeed, of men continually transform the face of our globe, and consequently alter the operations of natural causes; but, if the agency of animals be stimulated and determined solely by the influence of external objects, it follows that the re-actions of living beings are comprehended in the same necessary system, and that all the events within the immeasurable circuit of the universe are the successive evolution of an extended series, which, at the returns of some vast period, repeats its eternal round during the endless flux of time. Besides the grand cycle, there must evidently be many intermediate smaller periods, at the lapse of which our atmosphere will present nearly, though not exactly, the same fleeting aspects. Whether these bear any decided relation to the lunar revolutions, cannot with certainty be affirmed. · A copious collection of registers formed in the course of ages, will probably, at some future time, lead to the discovery of certain remarkable periods, which will enable men to conjecture, with tolerable precision, the succeeding changes of the weather. It would be most advisable, perhaps, to begin the inquiry with the tropical countries, in which the seasons are more uniform, and to advance by degrees into the temperate climates. In the mean time, our prognostications may be greatly assisted by observing and studying the concatenation of *phenomena*. Certain coincidences of aspects mark the near recurrence of some small portions of the general series, and afford scope for the doctrine of chances." (*Monthly Review for September* 1795, art. i. p. 14.)

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Necessity of recurring to correct observations.

Such views of the cyclical returns of the varied seasons may expand the imagination, but will be considered rather as curious speculations, than as definite conclusions which can ever be reduced to real and actual application. To improve meteorology, we must submit to tread a humbler path; we must study closely, and by the aid of delicate instruments, the constitution and modifications of the atmosphere, and pursue, under various circumstances, and in different parts of the globe, a lengthened train of careful and precise observations. The ordinary registers of the weather are of a very modern date, and, besides being for the most part unskilfully kept, they seldom record more than the state of the barometer and thermometer, which afford not any complete indication of the disposition of the atmosphere. No wonder than meteorology, though cultivated from the earliest times, has advanced the most slowly to the perfection of science.

To prepare the way for establishing meteorology on a solid basis, we shall *first* inquire into the extent and con-

stitution of the medium which we breathe; and shall *next* review the different philosophical instruments which assist external observation, and indicate at all times the exact condition and qualities of that mutable fluid.

Height of the atmosphere limited.

The ancients imagined that our atmosphere, the seat of care, mortality, and corruption, reached as far as the moon, beyond which was a boundless expanse of resplendent ether, the abode of celestial beings, exempt by their nature from all anxiety, and absorbed in the enjoyment of eternal bliss. But the discovery of the weight and pressure of the air destroyed at once this magnificent vision. Comparing the length of the mercurial column with the density of the aërial medium, it followed, that if the atmosphere had been an uniform fluid, it could not exceed the elevation of five miles. But the air being very dilateable, the higher portions of the mass which covers our globe, sustaining a diminished pressure, must swell upwards, and occupy a proportionally wider space. This property hence removes the boundary of the atmosphere to a much greater elevation. By means of an excellent pneumatic machine, air can be rarefied about a thousand times; but this degree of rarefaction would not occur below the height of forty-two miles in the atmosphere. Such is nearly the limit deduced from another consideration, first proposed by the famous Kepler. This most original and inventive philosopher conceived, that the depression of the sun below the horizon, when twilight closes around us, might furnish the data for discovering the altitude of the portion of sky which reflects his latest parting rays. Let C (see fig. 2, Plate CCCLV.) be the position of a spectator on the surface of the earth, and A represent the point where the sun sets; the tangent AB will mark the track of his lowest ray, which illuminates the upper part of the atmosphere at B, whence the emission of a secondary ray BC will barely reach the ground at A. But assuming the mean estimate of astronomers, that twilight expires when the solar depression or the arc CA amounts to eighteen degrees. In the right-angled triangle COB, the base OC, or the radius of the globe, being 3956, and the acute angle COB nine degrees, or the half of AOC, the hypotenuse OB is easily found, and hence about 49 miles is the excess BD of CB above CD, or the elevation of the boundary of the atmosphere, illumined by the latest beams of the sun. A correction might be required for the deviation of the rays from their rectilineal path, in consequence of the unequal refraction of the different strata of the atmosphere; but in a question of this kind, resting on rather loose or doubtful observations, it seems superfluous to affect any delicacy of calculation.

Lambert's investigation.

The inference drawn from the limits of twilight is not so conclusive as might at first appear. The feeble slanting rays, shed from the higher regions of the atmosphere, may not have been received directly from the sun, but derived, after repeated reflexions, from the more distant parts of the sky. The very ingenious Lambert attempted to distinguish, besides the primary twilight, a secondary, and even a ternary *crepusculum*. It is easy to see, that the solar ray SA (fig. 3, Plate CCCLV.), after grazing along the surface, will illuminate the upper atmosphere at B, from which some light will be darted in the direction of the tangent BCD, to tinge another elevated portion of the sky at D, which may cast a few expiring rays to the spectator at E, or shoot onwards to the opposite sky at F, and thence reach, in a state of almost extinction, the ground at G. Whilst the first *crepusculum*, therefore, sets in the west, the second will travel like a bow over the heavens, followed at a regular distance by the dusky veil of the third, or the vanishing train of the fourth. But it may be computed, from the vast length of the tracks which the light would have to traverse, that those shades would in succession be ten thousand times darker. The clearest sky, however, on the close of evening, never appears marked by such contrasted boundaries. The vault of heaven seems to darken by insensible transitions, from the western to the eastern horizon. It is most probable, therefore, that the diminution of light, after the close of evening, is owing to the prodigious rarefaction of much higher portions of the atmosphere, which still catch some faint rays of the sun, without being able, from excessive attenuation, to reflect them efficiently to the earth. But since, unless the sky be overcast, there is total darkness in no climate, even at midnight, we may therefore infer, that the body of air extends to such an altitude, as to receive the most dilute glimmer, after the sun has attained his utmost obliquity, and sunk ninety degrees below the horizon. It would thence follow, that the elevation of the atmosphere must be equal at least to 1638 miles, or the excess of the hypotenuse of an isosceles right-angled triangle having 3956 miles, or the radius of the earth, for its base.

Extreme elevation of our atmosphere.

This very great extension of a rare expansive atmosphere appears conformable to the general phenomena. But the thin investure of our globe, at least near the equator, may stretch out much farther; and yet its elevation can never exceed a certain absolute limit. The highest portions of the atmosphere, which is carried round in 23 hours and 56 minutes, by the rotation of the earth about its axis, would be projected into space, if their centrifugal force at that distance were not less than their gravitation towards the centre. But the centrifugal force is directly as the distance, while the power of gravity is as its square. Consequently, when the centrifugal force at the distance of 6·6 radii of the earth is augmented as many times, the corresponding gravitation is diminished by its square or 43·7 times, their relative proportion being thus changed to 289. Now, the centrifugal force being only the 289th part of gravity at the surface of the equator, it will therefore just balance this power at the distance of 6·6 radii from the centre, or at the elevation of 22,200 miles. On this hypothesis, fig. 7, Plate CCCLV. will represent our globe encompassed by its atmosphere, of which the equatorial diameter extends from A and B.

Such is the extreme boundary of atmospheric expansion. Though it surpasses all our ordinary conceptions of the space occupied by that dilateable fluid, it yet scarcely exceeds the twentieth part of the distance of the moon, which was held by the ancients to communicate with our atmosphere. If it really spreads out to the limit now assigned, it must, in its remote verge, attain a degree of tenuity which would utterly baffle imagination to conceive. Perhaps the fluid itself may change in those lofty regions, and pass into a sort of ethereal essence, more analogous to diffuse light than to a mass of air.

Constitution of the atmosphere.

The constitution of the atmosphere forms the next object of inquiry. The analysis of that rare medium is one of the finest discoveries of modern chemistry. It appears to consist of two distinct expansible fluids combined in different proportions, a single portion of oxygen gas being united to three parts by weight, or four parts by bulk, of azote. There is also a very slight admixture of carbonic acid gas, amounting to perhaps the thousandth part of the whole. It may be doubted, however, whether this analysis be complete. The combination of those gases obtained artificially, generates a fluid in which we can hardly recognise the ordinary qualities of atmospheric air. Some fugacious elements must therefore escape during the process of decomposition. Indeed, the air may be considered as an universal solvent. It is the medium of all smells, and must therefore dissolve the different odorous effluvia, and transmit them to the olfactory nerves. The presence of moisture may perhaps assist the solution, but the mass of air is still the great receptacle of those diffusive emanations. We can readily distinguish several earths and

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stones by their difference of smell. Nay, the metals themselves, especially when rubbed, emit peculiar odours. What can be more variously contrasted, for instance, than the smells of iron, of tin, and of copper? The air must hence actually dissolve some traces of those metals, highly attenuated indeed, and almost evanescent. If a lump of *assafœtida* loses but a grain by exposure for several weeks, a bright surface of copper may, in similar circumstances, suffer the waste of only the thousandth part of a grain. The metal, if not encrusted by oxidation, would consequently experience a certain diminution, however small, in the course of ages.

It is charged with various emanations.

The atmosphere is thus charged with emanations of all the various substances which it sweeps. To detect such dilute corpuscles wholly transcends the powers of chemical analysis. It seems probable, that the air holds some matters in more copious solution than others; and the phenomena of the aërolites lead us to suspect that it attracts iron and nickel with greater force than the rest of the metals. The quantity of those adventitious particles contained in a given mass of air may be exceedingly small, and yet the aggregate weight diffused through the whole atmosphere would form a considerable amount. It appears from numerous endiometrical observations, which agree tolerably well when performed in a similar way, that the constitution of our atmosphere is the same in all places on the surface of the earth, and at every elevation which has been yet explored. Such experiments have been made at very distant points, repeated on the summits of the loftiest mountains, and applied to portions of air brought down by balloons from the altitude of five miles. The result is what we should expect from the perpetual agitation and commixing of the lower strata of the atmosphere.

Its higher strata inflammable.

But a variety of circumstances render it extremely probable, that an expanse, far above the region of the clouds, is filled by some peculiar fluid, very different from the grosser element spread below. The shooting stars which are seen every clear night, the *bolades* or fire-balls, and the luminous arches which not unfrequently occur, and which must traverse the sky at the height of several hundred miles, all seem to indicate the existence of a very ignitible medium. Nor is it difficult to conceive how such a collection of highly inflammable fluids could be formed. Not to mention the multiplied processes of art which emit those products, the great laboratory of nature is incessantly at work in generating and pouring forth hydrogen gas, and its various compounds. The volcanic mountains cover a considerable portion of the surface of the globe; and their innumerable spiracles, with scarcely any interruption, continue to discharge immense streams of inflammable aërial fluids, a great part of which escape conflagration. But, as hydrogen gas has little attraction to common air, it rises upwards by its buoyancy, without suffering much loss in the passage through that fluid. The largeness of their volume, and the celerity of their projection, conspire to favour the ascent of those inflammable gases to the loftiest regions of the atmosphere.

A comparison of the several quantities of astronomical refraction, at different altitudes, points to a similar conclusion. The refraction which the rays of light suffer in slanting across the higher regions of the air, is greater than what calculation assigns to the corresponding density of the medium. But the discrepancy would entirely disappear, if we suppose those strata to consist of hydrogen gas, which is known to possess, in a remarkable degree, the power of refracting.

It seems very probable, that the higher range of atmosphere has a sort of phosphorescent quality, or shines with a certain feeble light, for some time, after it has been heated or excited by the incident rays of the sun. Such may be the principal cause, and not any reflex illumination, of that lucid glow which, even at midnight, is diffused over the clear canopy of heaven.

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Zodiacal light.

The phenomenon of what is called the *zodiacal light* might, perhaps, be traced to the same source. That remarkable appearance, which is more conspicuous in the finer climates, and near the vernal equinox, on the approach of evening, has often been ascribed to the extension of a supposed luminous atmosphere about the sun. But Laplace has shown, that such an atmosphere, far from stretching to our earth, would not even reach the orbit of Mercury. The zodiacal light must therefore have only a terrestrial origin. Supposing the uppermost regions of our atmosphere to consist of diffuse inflammable matter, we might infer from analogy, that, like the calcined sulphate of barytes and other incinerated substances, they are endued with a phosphorescent quality, and capable of scattering a lambent gleam on being excited by the beams of the sun. But this luminary darting perpendicular rays, will evidently affect most powerfully the range of atmosphere which occurs in his diurnal track. The expansion of the gaseous investure of our globe above the equator will hence, from its vast elevation, be descried in places even beyond the tropics, glowing with a gentle flame. The luminous cone which converges from the sun to the distance of perhaps 30 or 40 degrees in the circle of the equator, gradually contracts and grows fainter in proportion as that body sinks farther below the horizon.

It thus appears, that the opinion entertained by the ancient philosophers concerning the existence of a vast shining æthereal expanse beyond our atmosphere, is, with some modifications, consonant to the principles of sound philosophy. This is not the first occasion in which we have to admire, through the veil of poetical imagery, the sagacity and penetration of those early sages. It would be weakness to expect nice conclusions in the infancy of science; but it is arrogant presumption to regard all the efforts of unaided genius with disdain. Seldom has a discovery been made without some distant ray of anticipation.

Air may occupy the bed of the ocean.

Having ventured to state that the highest region of the atmosphere is probably occupied by some very diffuse phosphorescent gas, we shall hazard a conjecture which will appear bolder, and even paradoxical,—that perhaps air, in its most concentrated state, occupies the bottom of the ocean, and forms a vast bed, over which the incumbent waters roll. Air has actually been condensed above a hundred times, and during this process it betrayed no deviation from the fundamental law, that its elasticity is directly proportional to its density. There seems no reason, therefore, to doubt, that if an adequate compressive force could be exerted, air might be reduced to the thousandth part of its ordinary volume. But this elastic fluid would then be denser than water, and, consequently, instead of rising, would fall through the liquid. Suppose, for instance, a bladder filled with air, and having a small bullet attached to it, were thrown into the sea; in continuing to sink, it would reach a depth where the enormous weight of the column of water would compress it to the same density with the surrounding mass; and if the bullet were now disengaged, the bladder would remain suspended in that stratum, or if carried a little lower, it would precipitate itself to the bottom.

Hypothetical estimate.

To form some estimate of this singular event, a simple calculation will be required. Air of the ordinary temperature is 840 times lighter than distilled water, and is therefore 865 times lighter than sea-water, assuming the density of this to be 1·03. But the mean pressure of the atmosphere being equal to that of a column of thirty-four feet of distilled water, is hence equal to the weight of a column of $32\frac{3}{4}$ feet of sea-water. Wherefore $32\frac{3}{4} \times 864$, or 28,296 feet, is the depth of the ocean where the necessary compression would obtain. But a small correction

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must be applied, on account of the augmented density of the sea-water itself under the load of such a column. The logarithm of this density is found very nearly by multiplying the height of the column by six, and striking off seven decimal places; whence the *modulus* of the compression of water may be reckoned 723,824 feet. Of this large number, the former depth is about the twenty-fifth part; consequently, to procure an equilibrium between the condensed air and the corresponding stratum of sea-water, it is requisite that the air should be contracted one twenty-fifth part more, or reduced to 901 times less than its ordinary volume. But $32\frac{3}{4} \times 900 = 29{,}475$ feet, from which deduct the fiftieth part for the mean condensation of the column, and there remains 28,885 feet, the correct depth.

This computation is to be considered as only a near approximation, yet sufficiently accurate for the object in view. Nor shall we fatigue our readers by the investigation of a strict formula, including exponentials. It is enough to mark the conclusion, that any portion of air carried five miles and a half below the surface of the sea will never ascend again. Now, this limit is only half the depth which the theory of tides assigns to the waters of the ocean. There is more difficulty in conceiving by what process air can be conveyed to its abyss. Increase of pressure, however, enables water to hold a larger share of air; and the effect is hence the same as an augmented attraction. The minute globules of air may therefore be gradually drawn downwards from stratum to stratum, till they are at last detached from the body of water by their own superior density. The precipitation and accumulation of concentrated air under the ocean would thus be the results of some unceasing operation. Such a process may perhaps constitute a part of the great economy of nature. It seems probable, that the existence of a subaqueous bed of air is necessary to feed the numerous fires which continually rage in the bowels of the earth, and occasionally burst forth on the surface in volcanic spiracles.

Meteorological instruments.

The variable disposition of the atmosphere is the main cause of all the meteorological phenomena. It is of importance, therefore, to examine the theory and application of the different instruments which can be employed to explore the state of that medium. Some of these have been long in common use; but others, of a more delicate and refined construction, are only beginning to be known, and promise, when generally adopted, to expand our views, by opening a store of new and ulterior prospects. The ordinary observations are confined to the weight and temperature of the air. There are other data still wanted to determine at any time the actual condition of that medium. The dryness or humidity of the atmosphere, its brightness or degree of illumination, the different depth of the cerulean hue of the sky, and the variable disposition to chill the surface of the earth by impressions of cold transmitted from the higher regions; these objects of inquiry should be conjoined with others of a more practical tendency, depending immediately on the mutable state of the weather. Such are the attempts to measure the daily evaporation from the ground, to register the quantity of rain which falls, and to mark the direction and indicate the force or velocity of wind. A complete apparatus of meteorological instruments will, therefore, include primarily the *Barometer*, *Thermometer*, *Hygrometer*, *Photometer*, *Æthrioscope*, *Cyanometer*; and comprehend likewise the *Atmometer*, *Rain-Gage*, *Drosometer*, and *Anemometer*. We shall review this series in the order of enumeration.

Importance of the barometer.

I. Barometer.—The capital discovery of the weight and pressure of the atmosphere, achieved by Torricelli in 1643, was the first step in the progress of meteorology to the rank of a science. Prior to that memorable period it rested on principles altogether loose and conjectural. But the construction of the barometer, as an accurate instrument of observation, soon disclosed what was passing in the more elevated and distant regions of the atmosphere. The column of mercury, it was perceived, seldom remained long stationary, but rose and fell through a sensible space, according to the different state of the heavens. In fine calm weather it generally stood high, but commonly subsided a short while before rain or wind. The barometer came, therefore, to be regarded as a *weather-glass*, announcing the proximate changes of the sky, and owed its general reception to this belief. Its indications, however, were found by farther experience to be liable to much uncertainty. Though the extreme depression of the mercurial column appears invariably to foretell the ravage of a hurricane, yet its partial variations often pass away without being followed either by rain or wind. The barometer evidently can mark only the pressure of the atmosphere, and intimate, by consequence, the state of the weather, in as far as it depends on that cause.

Attempts to explain its variations.

Philosophers have eagerly sought to explain the fluctuations of the mercurial column. They have tried every principle that might appear to exert any influence in modifying the local weight of the atmosphere; but their very numerous attempts, it must be confessed, have hitherto proved singularly unsuccessful. It was requisite to show that such causes would not only give results of the kind expected, but were, besides, fully adequate to the production of the phenomena. In most instances, however, either none of those effects could have followed, or they would occur in a very inferior degree and disproportionate extent.

Influence of its heat.

All the proposed explications of the changes of the barometer may, perhaps, be referred to three distinct sources: 1. The action of heat on the atmosphere; 2. the influence of moisture on that fluid; and, 3. the impression made by its rapid motion in wind. Now, the heating or cooling of the air above any given place could in no way affect its pressure. The only change occasioned would be in the density of the fluid; and, by the influx of the portion below, or the efflux of a similar portion above, the pressure of the atmospheric column would soon become adjusted to an equilibrium with the surrounding mass. The diurnal variations of the barometer within the tropics, seldom exceeding the twentieth part of an inch, as they follow a different course from the progress of heat, are obviously not derived immediately from this cause. According to the accurate observations of Humboldt in South America, at all seasons the barometer falls from nine o'clock in the morning till four in the afternoon; it then rises till eleven at night, and from this time it again descends till half-past four in the morning, and next mounts till nine o'clock.

And of its dryness and moisture.

The transition of the air, from a state of dryness to humidity, seemed to furnish the most plausible explication of the changes of the mercurial column. But the indication of the barometer was, in this case, distinctly at variance with the ordinary feelings of men. Those who suffer under a delicate or enfeebled constitution are accustomed in damp weather to complain of the air as heavier and less elastic. This language is, no doubt, metaphorical only, and descriptive of the disordered state of the nervous system; but it shows the utter fallacy of trusting in philosophical matters to the loose results of vulgar observation and experience. Moisture, so far from loading the air by its weight, communicates, like heat, increased expansion and elasticity. But even supposing a column of air to become suddenly charged with humidity, before its subsequent dilatation had, by diffusing it, produced an equilibrium, still the additional pressure would have been extremely small, not exceeding, at a moderate computation, the fifteenth part of a mercurial inch. Any transition of that medium from dryness to humidity would be quite

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inadequate, therefore, to the production of the effects actually observed.

Some philosophers imagine that moisture, in separating from the air, ceases to press that fluid by its gravitation, and would hence explain the fall of the barometer on the formation of clouds and the precipitation of rain. But when the aqueous particles are disunited in their solvent, whether dispersed in minute globules or collected in large drops, they must evidently descend till they acquire the celerity sufficient to maintain a resistance in the medium equal to their weight. The pressure of the whole atmospheric mass upon the surface of the earth must therefore continue exactly the same under all the changes of the constitution of the medium.

Action of winds.

The combined action of winds seems at first to promise the most satisfactory explication of the variations of the barometer. It is evident that opposite currents rushing to the same quarter will occasion an accumulation of the air; and, on the other hand, different streams flowing from any point must reduce the vertical column. But such conclusions are quite vague, without being subjected to the ordeal of calculation. Now it is easy to compute that a concourse of winds, blowing at the rate of fifty miles an hour, and hence approaching to the violence of a hurricane, would be required to raise the barometer only the tenth part of an inch. The utmost power of a tempest could not, therefore, affect the mercurial column the twentieth part of what is frequently remarked in such circumstances. But trifling as this influence appears, it would be still at variance with actual observation. So far from rising in strong winds, the barometer almost invariably sinks; and instead of continuing depressed in the place where those currents originate, and where a calm must prevail, it generally stands high.

Hauksbee's experiment.

To explain the descent of the barometer during wind, a very ingenious idea has been proposed, which, being apparently confirmed by experiment, has obtained general reception. It is conceived, that a current of air, in sweeping over the surface of the earth, must cease to exert any vertical pressure. But this assumption can hardly be reconciled with any strict principle in science, for the particles of air will not for a moment cease to gravitate, nor will any horizontal motion of them produce the slightest derangement in a perpendicular direction. A remarkable experiment, however, was made by the ingenious Mr Hauksbee about the beginning of the eighteenth century, "showing," as he says, "the cause of the descent of the mercury in the barometer in a storm." Having connected the square box cisterns of two barometers by a horizontal brass pipe of three feet in length, he inserted in the side of one of the boxes another pipe opening outwards, and connected the opposite side with a pipe attached to the neck of a large globular receiver, into which three or four charges of atmosphere had been compressed. On turning the stop-cock, the imprisoned air rushed with vehemence over the surface of the mercury in the cistern, and effected its escape, while both columns fell simultaneously about two inches, and gradually rose again as the force of the blast diminished. From this experiment Mr Hauksbee formally derives four distinct corollaries: 1. "That we have hence a clear and natural account of the descent and vibrations of the mercury in violent storms and hurricanes;" 2. "That not only the different forces, but also the different directions, of the winds, are capable of producing a difference of the subsidence of the mercury;" 3. "That strong winds may affect the animal economy upon this very account, of their altering the pressure of the atmosphere;" and 4. "That the weight of the atmosphere being diminished in one place, it is also as much diminished at the same time in another place which holds a communication with the former."

Meteorology. Its fallacy.

This experiment has a specious appearance, and might even seem to warrant the conclusion drawn from it. But a closer examination dispels the illusion. Since the air had been condensed four times, it must issue from the receiver with the immense velocity of 2700 feet in a second, or the double of that with which air of the ordinary density would rush into a vacuum. This is a rapidity, however, twenty times greater than the most tremendous hurricane. The very small change of the four hundredth part of an atmosphere would hence have been sufficient to produce the strongest wind ever observed, and therefore its influence in passing over the mercurial surface must have been quite insignificant.

But the experiment itself was absolutely fallacious. The peculiar result proceeded from a mere casual circumstance, the exit-pipe from the mercurial cistern being wider than the pipe which introduced the current of air. This incidental arrangement is not mentioned in the description of the apparatus, and we have, therefore, caused the original figure to be engraved on a reduced scale, not only to prove the fact which we have just stated, but also to warn experimenters of the necessity of noting scrupulously every accessary circumstance blended in their operations. (See Fig. 2, Plate CCCLIV.) It is easy to perceive that the tube G, which discharges the air from the box F, is much wider than the tube E, which conveyed it from the receiver A. This air, previously condensed, and still restrained in its passage through E, on entering the cavity of the box, immediately expands beyond the limit of equilibrium, and finding an easy escape through G, allows that state of dilatation over the mercury during the time of the horizontal flow. But the air contained in the other cistern K must, from its communication by the slender pipe I, suffer a like expansion, and, consequently, the columns L and H will, in the same time, subside equally.

Similar experiments.

Such is unquestionably the true explication of this curious fact. Were any confirmation needed, it could easily be derived from a very simple experiment. Let A (fig. 3, Plate CCCLIV.) be any cylinder of tin, suppose three inches long and two inches in diameter, having an open pipe inserted at B, a quarter of an inch wide, and perhaps two inches long, and another opposite pipe inserted at C, about three eighths or half an inch wide, and one inch long; at right angles to these a recurved glass tube or syphon G H E, of the tenth of an inch bore, is cemented below, descending twelve inches, and rising again six inches to the open swell at E, which contains coloured water terminating at F. Holding the cylinder in a horizontal position, and applying the mouth at B, let a sudden blast be injected into the cavity; the water will rise instantly to G, thus showing the diminished pressure, and, consequently, the rarefaction of the air above it. But if a cap D, with a narrow projection of perhaps only the eighth part of an inch, be adapted to the exit-pipe C, on repeating the experiment, an opposite effect will take place, and the column of water, so far from mounting to G, will now sink to H. It is evidently the difficulty of the escape through D that occasions the accumulation of the air within the cylinder, and the consequent depression of the water in the syphon. These different results are perfectly analogous to the local fall or rise of the surface of a river occasioned by the widening or contracting of its channel.

New theory of the variation of the barometer.

After the complete failure of so many theories for explaining the variations of the barometer, which it would be tiresome to enumerate, we may be charged with presumption in attempting the solution of a problem that has racked and exhausted so much ingenuity. Yet in all these various efforts a principle seems to have been overlooked, of extensive influence, accordant with the general phenomena, and sufficient, we think, on a close investigation, to produce the measure of effect which is required.

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It is obvious that a horizontal current of air must, from the globular form of the earth, continually deflect from its rectilineal course. But such a deflection, being precisely of the same nature as a centrifugal force, must hence diminish the weight or pressure of the fluid. The only question is to determine the amount of that disturbing influence. Though it should appear quite inconsiderable in the interval of a short space, it may yet accumulate to a very notable quantity through the wide extent over which the same wind is known to travel. Suppose a current to begin to flow from A (fig. 9, Plate CCCLV.) in the direction of a tangent, it will successively bend from a rectilineal track at the points B, C, D, E, F, G, &c. on the surface of the earth. The particles of the fluid are, therefore, drawn incessantly from their course by the action of gravity. Their vertical pressure is consequently diminished by the force spent in producing this deflection. Wherefore, during the prevalence of the wind, the atmospheric column will press with inferior weight at B than at A, at C than at B, at D than at C; thus gradually decreasing through the whole chain. Suppose the intervals AB, BC, CD, DE, &c. to be each of them a mile, and that the current reaches the points B, C, D, E, &c. in successive minutes, a celerity which frequently happens; the deflection at B, owing to the curvature of the earth, would be eight inches, or two thirds of a foot; but the space through which a body would descend in a minute, by the action of gravity, is $60 \times 60 \times 16 = 57{,}600$ feet, or 86,400 times greater than the deviation from the tangent. Wherefore the atmospheric pressure would, on that hypothesis, be diminished by the 86,400th part for each interval of a mile from A to G. In the space of 288 miles this diminution would consequently be the 300th part of the incumbent weight; and over an extent of 2880 miles it would amount to the 30th part. If we assume the very probable estimate, that storms involve the whole region of the clouds, or attain an elevation of near three miles, the diminution of pressure, occasioned by a long series of deflections in the stream, would affect one half of the atmosphere. Wherefore, a wind which has blown over a track of 2880 miles, at the rate of 60 miles an hour, might cause the mercurial column to subside half an inch. If the velocity of the wind were doubled, which is probably the limit of the most tremendous hurricane, the fall of the barometer would be four times greater, and amount to two inches.

That the same powerful wind can sweep over an immense track of surface is well ascertained. The effects of a hurricane originating in the West Indies, at the distance of 5000 miles, have often been felt on our shores. But a wind arising at A must evidently be followed, at succeeding intervals, by a current from K, L, M, &c. the range of influence being thus extended over a larger track. During the flow of the air, the depression of the barometer at G will be maintained, or rather augmented.

Variation of the barometer the same over a great extent.

These conclusions are perfectly accordant with the facts observed. It appears, from comparing the most accurate registers, that the pressure of the atmosphere is subject to very nearly the same variations through a vast extent. A barometer may be considered as in unison with another placed at the distance of perhaps 200 or 300 miles, and the mercurial columns in both of them rise and fall by an almost simultaneous movement. But, in stormy weather, the separated barometers, however they may approximate in their indications, cannot absolutely correspond. The gradation of atmospheric pressure from G to F, from F to E, &c. may be very slow; and yet the minute differences may accumulate to a very sensible amount in the long range from G to A, or to M. Thus, though a barometer may stand only the twentieth part of an inch lower than another separated 200 miles, it would be half an inch below a barometer at the distance of 400 miles.

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The theory now stated seems to furnish the most satisfactory explication of a great variety of phenomena. Thus the minute diurnal alternations to which the barometer is subject within the tropics, are caused by the influence of the land and sea breezes. During the heat of the day those gentle airs blow from the ocean, and, therefore, near the shore, and in the interior of the islands, the mercurial column subsides. But after the vigour of the sun's beams has declined, they flow in an opposite direction, and consequently the mercury rises again. The fluctuations are only partial, however, because such breezes hold a very short sway, and do not perhaps extend beyond 100 or 200 miles.

The common remark, that a north-east wind, so far from depressing the mercurial column, generally causes it to rise, might appear at variance with the principles which we have advanced. But that wind which really comes from the north has probably a short course, and may be dependent on a more extensive current which maintains a flow in the higher regions towards the poles. The existence of opposite streams, though incompatible with the supposition of a wide-spreading hurricane, may yet be admitted in local and partial derangements of the atmosphere.

Hitherto we have contemplated the winds as describing only arcs of great circles about the earth; but they may be constrained to bend in smaller circles, and perhaps trace the parallels of latitude. Their flexure from a rectilineal course being in this case augmented, they would in the same extent exert an influence proportionally greater on the barometer. Such, near the arctic regions, may be the effect of a westerly wind of no very distant origin.

Explication of whirlwinds.

The same principles will explain the phenomena of eddies, whirlwinds, and tornados. Suppose (fig. 4, Plate CCCLV.) a horizontal stream of air, rushing from A to B, meets a contrary current blowing from C to D, and that some obstacle E occurs in their line of separation. The flow will evidently diverge on both sides of E (see figs. 5 and 6, Plate CCCLV.) till it swells by degrees into a vertiginous revolution. Such is the origin of the famous *malstroem*, or whirlpool, on the coast of Norway, occasioned by the meeting of opposite tides. The aërial vortices are evidently produced by a similar cause. If the opposite streams have equal force, the circulation will be maintained in the same spot; but if the one current flows with greater rapidity than the other, it will transport the vertiginous motion by the excess of its celerity. A motion of progression and revolution is thus upheld at the same time. Such appearances are frequently witnessed in summer, especially in the hotter climates. A whirlwind arises on a sudden, and runs over the surface of the ground, drawing into its vortex all the light substances which occur in the track. Immense havoc is often thus produced in the fields of rice and plantations of sugar-cane. It is easy to show, that if r denote in feet the radius of the extreme circle described by the whirlwind, and t the time of circumvolution in seconds, the elasticity, or pressure of the column at the verge will suffer a diminution corresponding to the fraction $\frac{5r}{4t^2}$. The amount of this diminution over the whole base would be reduced to three fourths; and consequently h, expressing the height of the revolving column of air, $\frac{15rh}{16t^2}$ would represent the mean effect of centrifugal action. Suppose the whirlwind to have an elevation of 200 feet and a radius of fifty, and to circulate in three seconds, the diminished pressure would be equal to the weight of a column of $\frac{15 \cdot 50 \cdot 200}{16 \cdot 9}$, or

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1040 feet. This example, assuming a celerity of sixty-five miles an hour, might be reckoned an extreme case, but it would occasion the mercury to sink in the barometer more than an inch, or 1·12.

The formula for the depression of the barometer caused by a rapid whirl or tornado in the lower atmosphere, may be changed into an expression that shall embrace the velocity instead of the time of revolution. This velocity in miles each hour being denoted by v, the diminished pressure of the vertiginous column will be $\frac{3v^2h}{50r}$. It thus appears that the effect is directly as the square of the celerity, and inversely as the radius of circumvolution. And since the rapidity of whirl can never exceed certain limits, the action of a tornado must diminish in proportion to the extent of surface which it occupies. Suppose the height of the cylinder of air to be 300 feet, the radius of the sweep 500 feet, and the celerity of its extreme circulation eighty miles an hour: Then $\frac{3\cdot6400\cdot300}{50\cdot500} = 230$ feet, which corresponds to a descent of 1·247, or about a quarter of an inch in the mercurial column.

II. The Thermometer.—The invention of this instrument has not only dispelled the illusions which formerly prevailed on the subject of heat, but has mightily contributed to extend our acquaintance with the actual condition of the atmosphere. A lump of iron brought into the house, from its exposure during a frosty night, feels intensely cold, yet becomes gradually warmer; and if it be put into the fire, it will soon grow extremely hot, till it acquires the faculty of burning. On removing it from the fire, and laying it again out of doors, it will, through all the steps of a contrary progress, relapse imperceptibly into its former state. This obvious fact, and many others of a similar kind, might have been sufficient to show that *hot* and *cold* are nearly relative conditions, which every substance is capable of assuming. The schools upheld very different notions, which, after a long series of descents, have at last found shelter among the vulgar. It was maintained that, of the four elements, air and fire are hot, and water and earth essentially cold; and that the compound bodies, from their constitution, partake of those qualities in different degrees. While the senses were the sole arbiters of heat and cold, substances became classed according to the sensations which they excited. If a body, such as lead, rapidly abstracted heat from the touch, it was reckoned cold. But the same quality was likewise bestowed on other substances of a very different kind, for instance, on vinegar and hemlock, because they affect the stomach with a sort of chilling sensation. Soft wood and feathers might be deemed warm, since they draw off heat feebly from the touch; but pepper was also ranged in the same class, because it stimulates the organs of taste. Such a confusion of ideas disfigured physical science, and perverted the practice of medicine.

Invention of the thermometer.

The construction of the air-thermometer, by the famous Sanctorio of Padua, in 1590, was the commencement of a salutary revolution. As it was at first intended for exploring disease, it has ultimately rendered signal service to the medical practitioners. About twenty years afterwards, those instruments were manufactured by Drebbel, who carried them from Holland into England. They were very rude, however, and adapted to no constant scale, but regarded merely as *weather-glasses*. The discovery of the barometer opened new views, and showed that the former instruments marked the conjoint effects of heat and pressure. To distinguish the separate influence of heat, it became hence requisite to employ some different fluid from air. Alcohol was preferred, as being very expansible; and, from the year 1655, thermometers consisting of rather wider tubes, terminating in balls or large bulbs filled with that liquid, were manufactured by Italian artists, who imitated an arbitrary standard adopted by the *Accademia del Cimento*. Such thermometers were clumsy, and susceptible of only a low range. Römer, who made the fine discovery of the progressive motion of light, proposed mercury, as a fluid sufficiently expansible, and capable of bearing an intense degree of heat. The origin of the scale was then fixed at the melting point of ice or snow, and the scale itself divided into degrees corresponding to the ten thousandth part of the capacity of the bulb. Yet this mode of construction seemed tedious, and liable to some inaccuracy. The capital improvement was made in 1724, by Fahrenheit, who took another standard point from the boiling of water under the mean pressure of the atmosphere. For many years that ingenious artist manufactured thermometers in Amsterdam on correct principles, very neat and small, adapted especially to medical purposes. The multitudes of young physicians who at that period studied in Holland quickly dispersed them to every part of the globe. The observations thus obtained gave juster ideas of the comparative temperatures of different climates, and in many cases reduced the exaggerations of travellers to moderate bounds. It thence appeared that the heat of the torrid zone was not so excessive, nor the cold of the arctic regions so intense, as had been commonly represented. The tropical plants could, therefore, enjoy in our hot-houses all the warmth of their native climate. The thermometer was first applied to direct the operations of horticulture, and afterwards extended to regulate the process of brewing and other arts more immediately depending on practical chemistry.

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Improved by Fahrenheit.

Congelation of quicksilver.

Quicksilver was deemed preferable to alcohol in the filling of the thermometers, not only because of the wide range which it embraces, but on account of the remarkable property which it was afterwards found to possess, of expanding equably with equal accessions of heat. But it failed in the lower part of the scale. The reported sinking of the mercurial thermometer in Siberia appeared to indicate an intensity of cold beyond all conception. But the discovery made by Professor Braun, in 1759, of the actual congelation of mercury itself, reduced the extent of refrigeration to moderate limits. This fluid metal suffers a large contraction in passing into the state of solidity; and, therefore, though it freezes about thirty-nine degrees below the zero of Fahrenheit, it yet shrinks through a space of more than a hundred degrees before it becomes fixed. As alcohol has never been congealed, though brought, in some experiments we could mention, to 150° below zero, thermometers filled with it are now employed to explore, if not to measure, intense cold.

Metallic thermometers.

Metallic thermometers are likewise well adapted for examining the state of the atmosphere. They are commonly constructed on the principle of the compensation balance of a chronometer, a spiral or circular spring being composed of two soldered opposite plates of distinct metals, for instance of brass and steel, or of zinc and platinum, which expand very differently under the action of heat, and therefore continually change their incurvation. Some instruments of this kind, made by Breguet at Paris, are remarkably elegant; and those more lately manufactured by that ingenious artist, with a very slender form, surpass all other thermometers in the exquisite sensibility of their indications. Fig. 9, Plate CCCLIV. represents the first form, reduced to about the fourth part of its natural size. The main piece of mechanism is a circular spring, fixed at one end, and composed of steel and brass soldered together. The other end carries a clip, that acts on a short train of wheels, which turn an index on the dial-plate, the extent of the scale, including the range of atmospheric tempera-

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ture. The dial with its index are shown by A; and B exhibits generally the interior mechanism. Fig. 4, Plate CCCLIV. delineates the latest improvement. To prevent the cracking or dislocation which a large motion of the spring sometimes occasions at the junction of the two metals, a thin plate of a third metal is interposed. Three plates, consisting of platinum, gold, and silver, are united by the rolling press into a single riband, of the thickness of only the 1200th part of an inch. The instrument is formed with about twenty-seven spires or circumvolutions of this very slender spring, bearing an index which travels in its circle over fifty centesimal degrees, or ninety degrees by Fahrenheit's scale. The metallic film is, from its extreme tenuity, almost instantly penetrated by the impressions of heat or cold, and the sensibility of this thermometer accordingly surpasses all conception.

Registering thermometers.

It is of much importance, in keeping meteorological journals, to have thermometers that shall indicate the extreme changes which occur during the absence of the observer, such as the greatest heat of the day, and the lowest cold of the night. For this object the metallic thermometers are easily adapted, since their index may push forward or draw back any moveable mark, and thus indicate the limits of its variation. Large mercurial thermometers, also, if mounted like the wheel barometers, to turn an index, will answer a similar purpose. But smaller instruments, though of a more complex construction, have been generally preferred. A sufficient account of the self-registering thermometer proposed by Lord Charles Cavendish in 1757, and of the more complete instrument described by Mr Six in 1782, may be found in any work which treats of the subject. The latter has now come into pretty general use, though we are sorry to remark, that it seems to have fallen into the hands of very inferior artists, the scale consisting merely of boxwood, rudely and inaccurately subdivided.

Both these instruments have been employed to ascertain the coldness of the ocean at great depths. It becomes requisite, however, to make some allowance for the contraction which the glass bulbs must suffer under the enormous compression of the superincumbent columns of water. This can easily be computed, from the effect of perhaps ten atmospheres in a condensing engine; and such corrections were actually applied to the observations made in Captain Phipps' voyage in 1773 towards the north pole. It is a matter of equal surprise and regret, that all such niceties were overlooked in the late expeditions of Captain Ross and Captain Parry to the arctic regions.

Those of Rutherford.

The simplest, and by far the best, self-registering thermometers, are those invented and constructed by the late Dr John Rutherford, of Middle Balilish, and first described in the Transactions of the Royal Society of Edinburgh for the year 1794. The one, which marks the *minimum*, is filled with alcohol, and the other, which indicates the *maximum*, is filled with quicksilver; and they are both attached to the same frame, or, what is still better, affixed to separate frames, placed nearly horizontal, or rather elevated about five degrees, to prevent the separation of the thread of liquid. The tubes have bores from the twenty-fifth to the fifteenth part of an inch wide, and include a minute tapered or conical piece of ivory, or of white or blue enamel, about half an inch long. This mark having in either thermometer its base turned towards the bulb, is drawn to the lowest point by the alcohol, which again freely passes it; but it is always pushed forward to the highest limit by the mercury, which afterwards leaves it. These marks, however, are now made cylindrical, a little thickened at the ends, and about three eighths of an inch in length. (See figs. 7 and 8, Plate CCCLIV.) Fig. 7 exhibits the alcohol or *minimum* thermometer; and fig. 8, the one which indicates the *maximum*, and is filled with quicksilver.

This instrument was first employed by Dr Rutherford, in some interesting experiments, to ascertain the temperature of germination, and determine the depth to which frost penetrates into the ground in different soils and situations, at the suggestion of his neighbour Dr Coventry, the very able and intelligent professor of agriculture in the University of Edinburgh, both of them proprietors in the small county of Kinross. The few instruments of this kind, for some time circulated, were made by the hands of the inventor; but artists have since learned to imitate and improve the original construction, and nothing is wanted now but to promote their diffusion. We regret that this very useful register-thermometer seems to be not yet so well known in London as it deserves.

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Differential thermometers.

The minutest changes which take place in the constitution of bodies are, for the most part, attended by corresponding alterations of temperature. To explore those abstruser operations of nature, which often betray the influence of more extensive principles, it was now requisite to improve the delicacy of the thermometer. To this object the writer of the present article had early turned his attention. At first he enlarged the capacity of the bulb, and thus procured degrees of such a size on the stem as to be capable of a very distinct subdivision. These instruments, however, received their impressions very slowly; and therefore tubes of extremely fine bores being selected, he had small bulbs blown, and filled with quicksilver, not in the ordinary way, but by the aid of a compressing force. With such exquisite thermometers, it was easy to procure much nicer observations, and to detect even the finer modifications of corpuscular action. But, to include the usual range of temperature, it was necessary to draw the stem to an immoderate length. The attempt to remedy this inconvenience led to the construction of the first kind of *differential thermometer*. The main object was evidently attained, if the mercury should always be made to start from some given point. The tube was therefore left open, and a cap adapted to the top, containing a surplus portion of the fluid. When the thermometer was kept inverted, this mercury closed round the orifice, and joined the thread in the stem, as in fig. 17, Plate CCCLIV. But when the instrument was reversed, the excluded fluid instantly separated, and sunk into the cavity under the top of the tube, as in fig. 16. In this situation, the descent of the mercurial thread in the stem marked the depression of temperature.

A differential thermometer of this construction was used for three or four years, in a variety of experiments, without ever failing. But an open thermometer must be liable to some uncertainty, and unavoidably subject to a continual deterioration. The loose mercury will undergo a slow oxidation, while the bore of the tube is apt to be soiled and tarnished by the insensible introduction of moisture. Such an instrument, however, is well adapted for many researches.

Its simplest form.

In the beginning of the year 1795, another form of the differential thermometer was devised, which, from its simplicity, its delicacy, and extensive application, has contributed essentially to the progress of physical and chemical science. This instrument is now so generally known, that a few remarks on its general construction will be here judged sufficient. The differential thermometer is a modification of the air-thermometer, but susceptible of the impressions of heat only, and exempt altogether from the influence of the variations of atmospheric pressure. The tube to which the scale is applied has a bore of equal calibre, from the fiftieth to the fifteenth part of an inch wide, the other branch being commonly wider; the terminating balls are not less than four tenths of an inch in diameter, and seldom exceeding an inch and a half. A glass tube, terminated by a ball containing air, is joined hermetically,

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or by the flame of a lamp, to another longer tube, terminated by a similar ball containing air also, but including a small portion of some coloured liquid. The tubes are then bent, generally into a recurved or double stem, like the letter U, and the liquid is adjusted to the proper height by making bubbles of air pass from the one ball to the other, from the little enlargement of the bore left at the junction of the tubes. If both balls have the same temperature, the liquid must evidently remain stationary; but if the ball of the shorter tube be warmed, the air, expanding and exerting more elasticity, will depress the liquid in the stem; or if this ball be cooled, the air, by its contraction, allows the liquid to ascend, from the superior elasticity of the air contained in the opposite ball. The fall or rise of the liquid will, therefore, mark the excess of heat or cold in the adjacent ball, and the space through which it moves will measure the precise difference of temperature.[1]

Its progressive improvement.

Alcohol and other volatile fluids were avoided in filling the tube, lest their vapour should affect unequally the elasticity of the air contained in the balls, and thus disturb the accuracy of the indication. Linseed oil tinged with alkanet root was first used; but it was found to be sluggish in its movements, leaving along the inside of the tube a sort of trail, which sometimes collected into globules. But the great objection to this and other fixed oils was, that they did not remain at the same point of the scale, but slowly shifted their place, owing, apparently, to a partial absorption of air in one of the balls, while their orange tint was found to fade away by exposure to the light. Deliquiate potash, coloured with archil, was next employed, and with tolerable success. By degrees, however, it deposited the colouring matter, and became almost limpid. Hydrogen gas, instead of common air, was then adopted for filling the balls. This mode of construction prevented the deposition of the colouring matter; but it was experienced to be troublesome, and attended with other impediments. After numerous discouraging trials, it was at last discovered that strong sulphuric acid tinged with carmine fulfils every condition, remaining permanently stationary in contact with confined air, and never losing in the slightest degree its colour from the action of the strongest light. Since the year 1801, this liquid has been constantly used in the construction of the differential thermometer. When the exhibition of striking effects rather than scrupulous accuracy is sought for, tinged alcohol, indeed, has in a very few cases been preferred, on account of the great facility and amplitude of its motions. But, in every instance, a column of liquid, terminating in the cavity of one of the balls, or in a small cylindrical reservoir under it, was preferred; and not, as proposed by some experimenters, a single drop of the liquid, which forces its way through the bore by successive starts, and is therefore liable to much uncertainty and derangement.

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Its different forms.

The differential thermometer is capable of some diversity of form. It may consist either of a single branch, pendant or horizontal, or it may be bent into two perpendicular branches, whether contiguous or placed at a short distance. Since the motion of the column in the tube is occasioned by the difference of the elasticity of the air contained in the two balls, it is not essential that those balls should be of equal dimensions; for an equipoise must obtain whenever the augmented elasticity of the air of the hotter ball is balanced by its expansion on the one hand, and the corresponding contraction in the opposite ball, joined to the pressure of the ascending column of the sulphuric acid. In general the balls are blown to a certain degree unequal, either to suit the particular instrument, or to please the eye; but in making observations, it must be kept invariably in the position for which it was designed, whether vertical or horizontal, since the pressure of the balancing column would be effected by an obliquity.

The differential thermometer, in its pendant form, and extended to a suitable length, from one foot, perhaps, to three or four feet, may be employed with great advantage in comparing the different temperatures of adjacent strata of air near the surface of the earth during the progress and decline of the day; and to detect the variations in a cloudy or a clear sky, and those occasioned by winds, as modified by the quality of the ground, whether naked or clothed with vegetation. But the main use of this instrument in meteorological researches arises from the various modifications of which it is susceptible. The minute changes of temperature which it marks discover the existence and intensity of other disturbing causes. It is thus found that fresh ploughed ground is more affected by the solar rays

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[1] It is not difficult to compute, in general, the size of the scale of the differential thermometer. Let the diameters of the two balls be expressed in inches by a and b, the diameter of the bore of the tube being denoted by d, and the measure of a centesimal degree by x. The capacities of those balls, π representing the ratio of the circumference to the diameter of a circle, would hence be $\frac{\pi a^3}{6}$ and $\frac{\pi b^2}{6}$, and the portion of liquid raised through the space x would be $\frac{\pi d^2 x}{4}$. Consequently the opposite elasticities exerted are $\frac{3d^2x}{2a^3}$ and $\frac{3d^2x}{2b^3}$, or, expressed by the altitudes of a column of sulphuric acid, of which 220 inches may be reckoned equivalent to the weight of the atmosphere, they become $\frac{660d^2x}{2a^3}+\frac{660d^2x}{2b^3}$, or $\frac{330d^2x}{a^3}+\frac{330d^2x}{b^3}$; wherefore, since air expands one 250th part for each centesimal degree, $\frac{330d^2a^3x+330d^2b^3x}{a^3b^3}+x=\frac{220}{250}$, and, by reduction, $x=\frac{22a^3b^3}{8250(d^2a^3+d^2b^3)+25a^3b^3}$. This corresponds to ten of the millesimal degrees adopted for the differential thermometer, but the length of an hundred of those degrees, which may be preferred as a larger basis for the scale, will be $\frac{44a^3b^3}{1650(d^2a^3+d^2b^3)+5a^3b^3}$. Suppose $a=\frac{3}{4}$, $b=\frac{4}{3}$, and $d=\frac{1}{35}$, of an inch; then

$$\frac{44\times\frac{27}{64}\times\frac{64}{27}}{1650\left(\frac{1}{1225}\right)\left(\frac{27}{64}+\frac{64}{27}\right)+5\times\frac{27}{64}\times\frac{64}{27}}=\frac{44}{\frac{1650}{1225}\times\frac{4825}{1728}+5}=\frac{44}{3\cdot76+5}=5 \text{ inches.}$$

If the balls be of equal diameters, this expression for the length of an hundred degrees in inches will become simply $\frac{44a^3}{3300d^2+5a^3}$. Thus, suppose $a=\frac{4}{5}$ and $d=\frac{1}{30}$ of an inch; then

$$\frac{44\times\cdot512}{\frac{3300}{900}+5\times\cdot512}=3\cdot62 \text{ inches.}$$

If the density of the sulphuric acid were reduced from 1·85 to 1·62, the expression for the length of ten degrees would pass into this very simple form, $\frac{a^3}{756d^2+a^3}$.

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than a green sward, on which also the breeze has little influence.

III. The HYGROMETER.[1]—The mutable condition of the atmosphere, as it inclines to dryness or humidity, is the main source of all the variety of meteorological phenomena. The changes which it undergoes with respect to moisture have a marked influence on a very numerous class of substances, and even on the animal frame. But unfortunately those indications are always vague, and often fallacious. To ascertain the portion of humidity which a given quantity of air holds, or is capable of sustaining, is a problem of the first importance; but our advances to the constructing of an instrument fit to measure with accuracy that disposition have been extremely slow.

Most substances of a loose and spongy texture, or possessed of an absorbent quality, are affected, though in very different degrees, by the presence of humidity. Accordingly, the variations, both in weight and bulk, which absorbent bodies undergo, have been employed to indicate the disposition of the air with respect to moisture. For this reason such substances are likewise termed *hygroscopic*, since they are always affected by the state of the ambient medium, though they may not precisely measure its degrees of humidity or dryness. But neither heat nor moisture is passively diffused, or yet shared among different bodies in equal proportions. From some experiments made by Sir John Leslie, it appears that, under a like change of circumstances, a hundred grains of ivory will attract from the atmosphere seven grains of humidity; the same weight of boxwood, fourteen grains; of eider-down, sixteen; of wool, eighteen; and of beech, twenty-eight. Other substances, in their respective measures of absorption, exhibit still wider differences.

Hygroscopes.

The dry or humid state of the air is therefore discovered from the variable weight of certain bodies exposed to its influence. Rock salt has been applied to that purpose; but potash, the muriate of lime, sulphuric acid, and most of the deliquescent substances, whether in a solid or a liquid form, act the most powerfully. Other materials of a firm or adhesive consistence manifest the same properties, though in a lower degree. Plates of slate-clay or of unglazed earthenware, the shavings of box or horn, paper or parchment, wool or down, all act as hygroscopes. But these substances, especially the harder kinds of them, unless they be extremely thin, receive their impressions very slowly, and hence they cannot mark with any precision the fleeting and momentary state of the ambient medium. Nor is the weight which they gain by exposure proportioned to the real dampness of the air; for the measures of their successive absorption are found to increase in a most rapid progression as they approach to the point of absolute humidity.

But to weigh the substances with the accuracy befitting such experiments is a very delicate and troublesome operation. Those thin bodies are liable, besides, to become in time covered with dust, which, while it must evidently augment their weight, cannot be detached from them without injuring their slender texture. The increase of bulk which they acquire from the portion of moisture attracted into their substance, furnishes therefore a more certain and convenient indication of the state of the atmosphere. The solid vegetable and animal fibres are connected by a fine soft netting, in which the power of absorption appears chiefly to reside. Hence the presence of moisture always enlarges the breadth of such substances, without affecting in any sensible degree their length. This effect is visible in the swelling of a door by external dampness, and in the shrinking of a pannel from the opposite cause. But the substances, such as paper or parchment, which have a diffused or interlaced texture, are extended by the absorption of humidity almost equally in every direction. On the contrary, twisted cord and gut, being swelled by moisture, suffer a corresponding longitudinal contraction, accompanied likewise, if not confined, by some uncoiling of their fibres.

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All these properties have severally been employed in the construction of hygroscopes. The expansion of the thin cross sections of box or other hard wood, the elongation of the human hair or of a slice of whale-bone, and the untwisting of the wild oat, of cat-gut, of a cord or linen thread, and of a species of grass brought from India, have at different times been used with various success. But the instruments so formed are either extremely dull in their motions, or, if they acquire greater sensibility from the attenuation of their substance, they are likewise rendered the more subject to accidental injury and derangement; and all of them in time appear to lose insensibly their tone and proper action.

Ivory hygroscopes.

An attempt was made by Sir John Leslie to revive the method of measuring the expansion of absorbent cohesive substances by their enlargement of capacity when disposed into a thin shell; and, by successive steps, he carried the hygroscope thus formed to as high a state of improvement as perhaps such an imperfect instrument will admit. A piece of fine-grained ivory, about an inch and a quarter in length, was turned into an elongated spheroid, as thin as possible, weighing only eight or ten grains, but capable of containing, at its greatest expansion, about 300 grains of mercury; and the upper end, which was adapted to the body by means of a delicate screw, had a slender tube inserted, six or eight inches long, and with a bore of nearly the fifteenth part of an inch in diameter. (See fig. 19, Plate CCCLV.) The instrument being now fitted together, its elliptical shell was dipped into distilled water, or lapped round with a wet bit of linen, and, after a considerable interval of time, filled with mercury to some convenient point near the bottom of the tube, where is fixed the beginning of the scale. The divisions themselves were ascertained by distinguishing the tube into spaces which correspond each of them to the thousandth part of the entire cavity, and equal to the measure of about three tenths of a grain of mercury. The ordinary range of the scale included about seventy of those divisions. To the upper end of the tube was adapted a small ivory cap, which allowed the penetration of air, but prevented the escape of the mercury, and thereby rendered the instrument tolerably portable.

Peculiarity of its contractions

This hygroscope was largely, though rather slowly, affected by any change in the humidity of the ambient medium. As the air became drier, it attracted a portion of moisture from the shell or bulb of ivory, which, suffering in consequence a contraction, squeezed its contained mercury so much higher in the tube. But if, on the contrary, the air inclined more to dampness, the thin bulb imbibed moisture and swelled proportionally, allowing the quicksilver to subside towards its enlarged cavity. These variations, however, were very far from corresponding with the real measures of atmospheric dryness or humidity. Near the point of extreme dampness, the alterations of the hygroscope were much augmented; but they diminished rapidly as the mercury approached the upper part of the scale. The contraction of the ivory answering to an equal rise in the dryness of the air, was found to be six times greater at the beginning of the scale than at the seventieth

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[1] From ὑγρος, *wet* or *humid*, and μετρον, *a measure*. *Hygrometer* is distinguished from *hygroscope*; the former *measuring* the humidity of the air, the latter only vaguely marking its presence.

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hygroscopic division, and seemed in general to be inversely as the number of hygrometric degrees, reckoning from twenty below. Sir John Leslie therefore placed another scale along the opposite side of the tube, the space between the zero and the seventieth division of the hygroscope being distinguished into 100 degrees, and corresponding to the unequal portions from the number twenty to 120 on a logarithmic line. This very singular property will be more easily conceived from the inspection of the figure. The scale might probably be extended farther by continuing the logarithmic divisions. Thus, 320 degrees by the hygrometer would answer to 108 of the hygroscope, or to a contraction of 108 parts in a thousand in the capacity of the bulb. But at the dryness of 300, the contraction of the ivory seemed never to exceed 105.

Boxwood was likewise formed into a hygroscope of the same shape and dimensions; but this absorbent material swells twice as much with moisture as ivory does, and therefore requires its inserted tube to be proportionally longer or wider. Its contractions are still more unequal than those of ivory; for, near the point of extreme humidity, those alterations in the capacity of the bulb appeared to be more than twenty times greater than, under like changes in the condition of the atmosphere, take place towards the upper part of the scale. The space included between the commencement and the hundred and fortieth millesimal division of the scale might hence be marked with a hundred hygrometric degrees, corresponding to the decreasing portions of a logarithmic line from five to a hundred and five.

In noticing the rapidly declining contractions which ivory and boxwood undergo, Sir John Leslie did not mean, however, to state the quantities with rigorous precision. Much time had been consumed in attempting to trace out the law of those gradations; and such experiments are rendered the more tedious, from the protracted action of the hygroscope, which often continues travelling slowly for the space of a quarter, or even half an hour. This tardiness is indeed the great defect of all instruments of that nature, and utterly disqualifies them for every sort of delicate observation.

The very large expansions which the hygroscope shows on its approach to extreme humidity, explains in a satisfactory manner the injury which furniture and pieces of cabinet work sustain from the prevalence of dampness. On the other hand, the slight alteration which the instrument undergoes in a medium of highly dry atmosphere, seems to have led most philosophers to believe that there is an absolute term of dryness, on the distance of which from the point of extreme moisture they have generally founded the graduation of the different hygroscopes proposed by them. This opinion, however, is far from being correct, and might give occasion to most erroneous conclusions. No bounds can be set to the actual dryness of the air, or the quantity of moisture which it is capable of holding, which, by the joint application of heat and rarefaction, may be pushed to an almost indefinite extent.

The ivory hygroscope, after being for several hours immersed in air remarkably dry, was apt of a sudden to split longitudinally. But if the bulb endured such a range of contraction, it appeared in some instances to take at least *another set*, or to accommodate its constitution, by imperceptible changes, to the state of the surrounding medium.

But though the bulbous hygroscope is, in extreme cases, liable to much uncertainty and some risk, it may yet be used with visible advantage in certain peculiar situations. The very sluggishness of the instrument, when the value of its divisions has been once ascertained, fits it so much the better for indicating the mean results. After being long exposed in situations hardly accessible, it may be conveniently transported for inspection, before it can suffer any sensible change. The hygroscope could be therefore employed with success to discover the degree of humidity which prevails at considerable elevations in the atmosphere. It might be likewise used for ascertaining readily the precise condition of various goods and commodities. Thus, if the bulb were introduced, for the space perhaps of half an hour, into a bag of wool, a sack of corn, or a bale of paper, it would, on being withdrawn from their contact, mark the dryness or humidity of those very absorbent substances.

Other hygroscopic substances have at different times been proposed, which, though possessed of greater sensibility, are yet liable to the same general objections. Thus, quills, reeds, gold beaters' skin or pellicle, the skins of frogs, or the bladders of rats, were made to act like the bulbs of thermometers, and to cause, by their contraction or dilatation, as they inclined to dryness or humidity, the included quicksilver to rise or fall in rather a wide tube. These instruments, however, being subject to injury or derangement from the smallest accident, can scarcely be applied to any practical use.

The hygroscopes which depend on the elongation of the fibres are perhaps on the whole preferable. The slice of whalebone proposed by M. Deluc, and the human hair afterwards employed by M. de Saussure, are both of them sufficiently sensible to external impressions; but the difficulty is to determine the precise relation subsisting between those impressions and the state of the atmosphere. Humidity is not distributed in equal shares through the air and among the several absorbent substances exposed to its penetration; nor are the degrees of expansion which it communicates either uniform or proportional to its quantity. The graduation of such instruments, being thus in a great measure arbitrary, can furnish no correct data of the hygrometric state of the atmosphere. The assumption of two fixed extreme points as the basis of the scale is evidently erroneous. Air contained within a glass receiver may be rendered as damp as possible, by the copious aspersion of water on the sides; but it can never be absolutely deprived of its moisture, which adheres the more powerfully in proportion as it becomes diminished. Caustic alkalis, concentrated acids, and some of the deliquescent salts, aided by the action of heat, all render the air drier, but without being able to complete the desiccation. By the combined application of other agents, and even by mechanical pressure, the driest air can always be made to deposit some farther portion of moisture.

M. de Saussure directed all the resources of his ingenuity to correct the anomalies of the instrument which he proposed, and at last succeeded, by multiplied precautions, in rendering it as perfect, perhaps, as its nature and composition will admit. The hair-hygroscope (for it is not entitled to the name of hygrometer) certainly shows mobility; but the degrees which it marks can afford no steady or tolerably correct estimate of the dryness of the atmosphere.[1]

Expansion hygrometer.

To arrive at an accurate measure of the dryness of the air, it is necessary to pursue a different route. Steam, in whatever way it be formed, whether by the application of heat, or the diminution of atmospheric pressure, has near-

[1] From the few observations which we have made with an instrument of this kind brought from Geneva, we are sorry to say that it falls much below our expectations. Its motions are slow and irregular; and it seems to be little affected by very considerable alterations of the state of the encircling medium.

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ly the double of the elasticity of common air, or it would, under the same compressing force, occupy about twice as much space. In uniting with that fluid, and forming vapour, it must hence communicate an expansion exactly proportional to the quantity dissolved, or to the share of moisture required for the complete saturation of the air. This principle suggested to Sir John Leslie the means of constructing an accurate hygrometer, to which his researches had been early directed. Inverting a barrel-tumbler, he ground the mouth perfectly flat, and having drilled a hole through the bottom, he cemented into it a syphon-gage, or slender recurved tube, with a narrow bore, and an intermediate swell or cavity, passing through a perforated cap of lead, and holding a portion of nut oil, tinged with alkanet root. (See fig. 6, Plate CCCLIV., where it is represented half the natural size.) To form the scale, he divided 4·2 inches into an hundred equal parts, so that each degree corresponded to the ten thousandth part of the air's elasticity, the whole atmospheric pressure being equal to that of a column of the oil 420 inches in height. Having now spread a few drops of water over a surface of plate glass, and slipped the tumbler upon it, the included air quickly dissolved as much moisture as was sufficient for its saturation, and marked the expansion thence acquired, by forcing the oil to rise proportionally. The quantity of effect varied much, but was often very considerable, amounting, in fine weather, to 110 or 120 degrees. This little apparatus appeared to answer the purpose intended; but it was not portable, and it always required some address. It soon gave way, therefore, to other instruments, which promised to be more easily and readily managed.

As an hygrometer of this kind exhibits the actual expansion or increase of elasticity which the air acquires from complete humefaction, it seemed calculated for indicating the variable power of a drier or a moister atmosphere in refracting the rays of light. The barometer and thermometer had long been employed to correct the quantity of refraction; but the application of an accurate hygrometer seemed no less necessary for delicate observations. An instrument of the composition now described was accordingly intrusted, in the course of the year 1794, to the late Dr Maskelyne, and deposited in the Royal Observatory of Greenwich. Other objects, however, interfered, and an investigation, which promised important results, was never prosecuted on a regular and digested plan.

Its compound form.

This instrument might be rendered still more accurate, by combining it with the principle of the differential thermometer. Let two similar tumblers (see fig. 5, Plate CCCLIV. where it is contracted to about the fourth part of its size), A and B, inverted and loaded, have their mouths ground to fit a glass plate, the air contained in each of them acting by its elasticity on the column of a recurved tube C, which connects their cavities. Slide both of these tumblers in a dry state upon their bases, dip a hair-pencil in oil, and pass it round the outside of the mouth of A, to make it quite tight; then having removed B, and spread a few drops of water over its place, slip it on the plate again. The air included in B, now absorbing moisture, will continue to expand and to press upon the liquid column, till it has become absolutely saturated. Should any change take place in the temperature of the room during this process, it can have no effect in deranging the indication of the instrument, since it must influence precisely in the same degree the elasticity of the air contained in both balls, and thus produce an exact counterbalance.

Mode of ascertaining alterations in bulk.

This compound instrument is adapted to various delicate physical inquiries. In the union of different substances, a certain alteration of volume, however minute, almost invariably takes place. To ascertain such changes under various circumstances greatly extends our views of the empire of chemical affinity. For instance, a small bit of fresh charcoal introduced under one of the tumblers will mark its absorption of the air, by the consequent rising of the coloured liquid. But the tumbler being wetted over the inside, and a portion of dry, though not recent, charcoal, with a pared surface, placed within it, after the air has ceased to dilate from humefaction, if the charcoal be brought in contact with water, the liquor will again rise, and continue for some time to indicate a renewed expansion. As the water is imbibed by the charcoal, minute globules of air will appear to escape. But if the water, by its insinuation, had merely dislodged the air from the pores, there would have been no change of volume, and consequently no alteration in the height of the liquid on the scale. Those aërial globules must have, therefore, expanded as they emerged, or they had existed in a state of condensation united to the charcoal.

On the other hand, if a roll of unsized paper, linen rags, slips of wood, or saw-dust, be successively introduced under a tumbler in which a little water is easily shed, the coloured liquor will sink rapidly in proportion as the moisture is absorbed. In this case, there is an obvious diminution of volume, and an union produced between a liquid and a solid, quite analogous to chemical solution; whereas capillary action, such as the ascent of water through sand, is attended by no change whatever of the space occupied by the compound.

Another application of this instrument was to place under the tumbler separate capsules containing different substances, liquid or solid, which exert a mutual attraction. The included air in this case served as the vehicle of transfer, and a sort of distillation was supported, of a peculiar kind. The indications of this invisible process were variable, and often striking. But to enlarge on this subject would be foreign to our purpose. We have only taken the opportunity of noting a few of the results of an inquiry which was not pushed to any extent, but which deserves to be resumed, as likely to open new paths, and to unfold the more abstruse relations subsisting among different bodies.

Confused ideas of the process of evaporation.

Philosophers have long entertained very crude notions respecting the union of moisture with air, and the different circumstances which regulate or influence the process of evaporation. Dr Halley supposed that fire, uniting with the particles of water, communicates a vesicular constitution, which enables them to rise and spread through the atmosphere. A similar idea was entertained by Leibnitz, and was extended still farther by Muschenbroeck and Desaguliers. Kratzenstein adopted the vesicular system in 1743, and endeavoured to calculate the attenuation of the fluid which should produce the requisite buoyancy. Hamberger, in 1750, advanced, however, a capital step, by rejecting that hypothesis entirely, and attributing evaporation at once to a real solution of moisture in the air. This simple theory was in the following year explained at large by Le Roi of Montpellier, and fortified by some striking arguments drawn chiefly from analogy. In pursuance of his theory, he proposed to pour ice-cold water into a deep glass, and to ascertain the dryness of the air, by noting the depressed temperature at which the dewing or deposition of vapour began to form on the outside of the glass, or was again about to disappear. Could this method have been easily and nicely reduced to practice, it might certainly have furnished an accurate estimate of the hygrometer and state of the atmosphere.

Wallerius, in his researches, was drawn aside from the right path, by a fact first noticed by Muschenbroeck, who asserted that evaporation is always more copious from a deep than from a shallow vessel; and this curious and apparently anomalous fact has been confirmed by other sub-

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sequent experiments. But he found, from a series of careful observations, that the quantity of water exhaled in the same situation is exactly proportional to the extent of surface exposed. He likewise made some experiments which seemed to furnish an explication of the peculiarity remarked by Muschenbroeck, though their force was not generally perceived at the time. But Richman rather darkened the subject by his strange conclusion, that the measure of evaporation depends on the difference merely between the temperature of the air and of the water, whether in excess or defect.

It was not difficult to perceive that evaporation is promoted by the application of heat, and the agitation of the aërial medium. No attempts, however, were made to determine the relation of that augmented effect to the actual velocity of the wind. But experiments on the influence which an increase of temperature exerts on the quantity of evaporation have been prosecuted with various success by Lambert, Saussure, and Kirwan. The results thus obtained unfortunately differ very widely; and though the researches of the celebrated naturalist of Geneva were those conducted with the most care and address, yet they seem, from the vagueness of their elements, not entitled to much confidence.

Vague explication of the cold produced by it.

If the estimate of the causes which regulate the quantity of evaporation was unsatisfactory, still more perplexing appeared the ordinary account of the source of that depression of temperature which always accompanies the process. It was commonly referred to the operation of different concurring circumstances, among which the agitation of the air was conceived to perform the principal part. The dryness of that medium, on which we shall find the effect alone to depend, was in a great measure overlooked, or was confounded with other occasional agents. An evident confusion of ideas prevailed. The celerity of evaporation was mistaken for its intensity, and the coldness induced on the exhaling surface was viewed as the accumulated effect of a rapid dissipation of moisture. It was not perceived that in a free atmosphere vaporization proceeds with unabated energy, while the corresponding depression of temperature must advance by a relaxing progression, since otherwise the accession of an accelerated movement might push it to any extent. A little reflection, indeed, should have convinced philosophers, that the reduced temperature caused by vaporization must, in given circumstances, have a certain limit beyond which it cannot pass. But simple as this conclusion may now appear, it had escaped the most sagacious inquirers. Even Saussure, a patient and accurate experimenter, persuaded himself that, when water evaporates slowly, the cold produced is scarcely perceptible. To render this sensible, therefore, he thought it necessary to accelerate evaporation. Inserting the ball of a thermometer in a wet sponge, and attaching a cord to its stem, he whirled it briskly round his head, and thus produced a cold of eighteen degrees by Fahrenheit's scale, which he considered as much greater than could be obtained by other processes. To prosecute the inquiry, he had a sort of whirling table constructed, of about five feet diameter, by means of which a thermometer, with its bulb incased in wet sponge, could be made to revolve with the velocity of forty feet in a second. This machine he was at the trouble and expense of having carried up to the summit of the Col du Géant, where, during a residence of several days, he performed a series of interesting and valuable experiments. It did not occur to this philosopher, that by such a contrivance he was only creating to himself a vast deal of unnecessary fatigue, and that his wet thermometer, if left simply at rest for the space of two or three minutes, would have indicated exactly the same results. By all his exertions, he merely shortened the very moderate time required for attaining its extreme limit of depression.

Such were the imperfect notions which still prevailed on the subject of evaporation so late as the year 1796, the date of the publication of the last volume of the *Voyages dans les Alpes*. It is curious to remark, that Dr Black, in his Lectures, never mentions the dryness of the air as any way promoting evaporation, but ascribes the acceleration of the process entirely to the warmth and agitation of that medium. His friend Dr James Hutton, whose acuteness and penetration were conspicuous, had probably studied the phenomenon more closely. "I never had a hygrometer," he says; "but I used to amuse myself in walking in the fields, by observing the temperature of the air with the thermometer, and trying its dryness by the evaporation of water. The method I pursued was this: I had a thermometer included within a glass tube, hermetically sealed; this I held in a proper situation until it acquired the temperature of the atmosphere, and then I dipped it into a little water also cooled to the same temperature. I then exposed my thermometer, with its glass case wetted, to a current of air; and I examined how much the evaporation of the atmosphere, by holding the ball of the thermometer, or the end of the tube in which the ball was enclosed, towards the current of air; and I examined how much the evaporation from that glass tube cooled the ball of the thermometer which was included." He then proceeds to relate some hasty and very inaccurate observations made in this way. The passage now quoted occurs in a quarto volume published in 1792, buried in a repulsive mass of diffuse reasoning and paradoxical speculation, unsupported by any definite experiment. But Dr Hutton had evidently considered it as a conjectural hint, on which he laid little stress; for he speaks immediately afterwards of our possessing accurate hygrometers, which could not be admitted if the assumption he seemed to make had been strictly true.

Analysis of the operation.

Whilst such loose and imperfect notions prevailed respecting evaporation, it was expedient to review the process with attention, and analyse the several changes which accompany it. The depression of temperature which it always occasions had been hastily supposed to be proportional to the rate with which the moisture is dissipated, and to be therefore augmented by every circumstance that can accelerate this effect. But if water contained in a porous vessel expose on all sides its surface to a current of air, it will cool down to a certain point, and there its temperature will remain stationary. The rapidity of the current must no doubt hasten the term of equilibrium, but the degree of cold thus induced will be found still the same. A little reflection may discover how this takes place. It is well known that the conversion of water into steam is, in every case, attended by the absorption of the heat requisite to support a gaseous constitution. Though the humid surface has now ceased to grow colder, the dispersion of invisible vapour, and the corresponding abstraction of heat, still continue without intermission. The same medium, therefore, which transports the vapour, must also furnish the portion of heat required for its incessant formation. In fact, after the water has been once cooled down, each portion of the ambient air which comes to touch the evaporating surface must, from its contact with a substance so greatly denser than itself, be likewise cooled down to the same standard, and must hence communicate to the liquid its surplus heat, or the difference between the prior and the subsequent state of the solvent, which is proportioned to the diminution of temperature it has suffered. Every shell of air that in succession encircles the humid mass, while it absorbs, along with the moisture which it dissolves, the measure of heat to convert this into steam, does at the same instant thus deposite an equal measure of its own heat on the chill exhaling surface. The abstraction of heat by vaporization on the one hand, and its deposition

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on the other, at the surface of contact, are therefore, opposite contemporaneous acts, which soon produce a mutual balance, and thereafter the resulting temperature continues without the smallest alteration. A rapid circulation of the evaporating medium may quicken the operation of those causes; but so long as it possesses the same drying quality, it cannot in any degree derange the resulting temperature. The heat deposited by the air on the humid surface becomes thus an accurate measure of the heat spent in vaporizing the portion of moisture required for the saturation of that solvent at its lowered temperature. The dryness of the air is, therefore, under all circumstances, precisely indicated by the depression of temperature produced on a humid surface which has been exposed freely to its action.

It may insure perspicuity, however, to recapitulate the great principle on which the formation of the hygrometer depends. When water passes into steam or vapour, it enlarges its capacity, and absorbs a very large share of heat. Any body, therefore, having a wet surface, becomes generally colder, if exposed to the access of air. But this decrease of temperature soon attains a certain limit, where it continues stationary, though the dissipation of moisture still proceeds with undiminished activity. The same medium which transports the vapour must hence furnish also the portion of heat required for its incessant formation. In fact, after the humid surface has been cooled, each portion of the ambient air which comes to touch it must likewise be cooled down to the level of the dense substratum. The addition of heat at the surface of contact is thus a contemporaneous act with its subtraction by the process of vaporization; and it quickly advances to the same degree of intensity, after which a mutual balance of opposite effects is maintained, and the coolness hence induced continues unaltered. An augmented circulation of the evaporating medium may hasten the process; but while it has the same drying quality, it cannot in the least affect the depression of temperature. As soon as such an equilibrium is attained, the deposition of heat on the humid surface must become just equal to its abstraction. But this deposition is evidently proportional to the diminution of temperature, which is hence a measure of the share of heat abstracted, and therefore of the dryness of the air, or its distance from saturation.

Confirmed by experiment.

This analysis of the process of evaporation appears so conclusive as to banish all doubt and objection. But it was desirable to confirm the deductions of theory by an appeal to direct observation. Accordingly, on setting the hygrometer upon a table in the middle of a room, and blowing from some distance against the wet ball with a pair of bellows which had acquired the temperature of the apartment, the instrument still indicated the same measure of dryness. The experiment was repeated more accurately on a larger scale, by exposing the hygrometer out of doors to the action of a strong and arid wind, a small screen being interposed and again removed, at short intervals of time, during which alternations no change whatever could be perceived in the quantity of the depression of temperature.

Having, therefore, ascertained the great law of evaporation, and proved that the coldness occasioned by it is not in any degree affected by agitation or other extraneous influence, nothing seemed wanting to construct an *hygrometer* on just principles, but to contrive a thermometer that should mark the smallest alterations of temperature. At first Mr Leslie employed a very delicate thermometer with a short range, open at the top, where a small cap of glass or ivory was fixed, containing a small portion of surplus quicksilver. (See fig. 16 and 17, Plate CCCLIV.) When this thermometer was heated by the hand till the thread of quicksilver filled the whole of the stem, and formed a little globule at the top, it was inverted, as in fig. 17, and all the quicksilver united into one mass; but when it was restored, as in fig. 18, to its first position, the quicksilver fell back from the cap, and lodged about the end of the stem, leaving the bore completely filled. A cup (see fig. 1, Plate CCCLIV.) made of thin porous earthenware, nearly of the shape of a lady's thimble, but somewhat larger, and filled with water, was exposed to the air, while the thermometer lay beside it in a horizontal position. After a few minutes, the thermometer was lifted up and plunged vertically into the cup; and the thread of quicksilver, which had extended through the whole length of the bore, being by this change of position cut off at the top of the tube, immediately contracted, and marked, by the space of its descent, the diminution of temperature in the liquid.

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Leslie's hygrometer.

The very severe winter of 1794–5 afforded Sir John Leslie an opportunity of making experiments on the evaporation of ice; in the course of which he was led to the construction of the differential thermometer, now so generally known. At first he employed it merely as an hygrometer, the one ball being always naked, and the other covered with cambric, wetted as often as occasion required. These balls were about an inch and a half in diameter, and blown to the ends of the same tube, one of them having a projecting point or aperture, which was sealed, after the branches had been bent and a portion of coloured oil introduced. The graduation of the scale was determined by placing the instrument erect between two boxes, each containing a body of water, which encompassed one of the balls, and by noticing the rise of the oil on changing the relative temperature of the bath. An hygrometer, thus formed, was sent to the late Sir Joseph Banks, in the summer of 1795; and Mr Gilpin, clerk to the Royal Society, deposited a copy of it in their cabinet. But this model is so rude and clumsy, as hardly to recall the original. In the hands of the inventor, however, the instrument was soon improved, and reduced to a convenient and portable size. He had the satisfaction of showing an hygrometer of this construction, in January 1796, to Dr James Hutton, only a few months before the death of that very ingenious philosopher, who was delighted with seeing the application of a principle which he readily comprehended, and which his sagacity had obscurely anticipated.

But the sluggishness of the oil, and its tendency to deposite its colouring matter, on exposure to the influence of light, still opposed obstacles to the perfection of this hygrometer. These were entirely removed, however, about the year 1801, by the substitution of concentrated sulphuric acid tinged by carmine. The most powerful and continued action of the solar beams was found to produce no change whatever on that purpurine liquid, when precluded from the access of the external air. Any improvements which have since been effected on this instrument consist chiefly in its mechanical arrangement, in the selection of the tubes, the better proportion of the balls, and the elegance and conciseness of the general shape.

Its construction.

The hygrometer has two distinct forms; the one *portable* and the other *stationary*. The former (see fig. 13, Plate CCCLIV.), having its balls in the same perpendicular line, is protected by a wooden or metallic case, and fitted for carrying in the pocket; two or three drops of pure water, from the tip of a quill or a hair pencil, being applied to the surface of the covered ball, and the instrument held exactly in a vertical position whenever it is used. The latter form (see fig. 12) is susceptible of rather greater accuracy, having its balls bent opposite ways at the same height. In some instances, it is preferable to retain merely the simplest form of the differential thermometer, the vertical stems being more distant, and the balls not reflected. In both these constructions, the two balls, since they occupy

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the same level, cannot be affected in the smallest degree by the unequal temperatures of the different strata of air in a close heated room. After the covered ball has been wetted, the instrument will continue to perform unimpaired, for the space, perhaps, of two or three hours. The addition of a few drops of water will then restore its action. But the hygrometer may be made to supply itself with moisture. It is only wanted to pass some fibres of floss-silk close over the humid ball, and immerse them at the distance of a few inches in a tall glass decanter, full of water, with a stopper which leaves open a small projecting lip.

The hygrometer has its opposite balls made to exhibit nearly the same colour and opacity, in order to exclude the admixture of photometrical influence, or prevent any derangement which the unequal action of light might otherwise occasion. The naked ball is blown of red, green, or blue glass, and the papered one is externally covered with thin silk, of rather a fainter shade, as it takes a deeper tint when moistened.

Its theory completed.

The theory which we have given of the hygrometer, corroborated by its accurate performance, might appear complete in every part. But the progress of science commonly detects the existence of some collateral causes which come to mingle their influence with the action of the great dominating principles. In our explication of the hygrometer, we stated that the same air which *abstracts* moisture, and consequently the portion of heat necessary to convert it into the gaseous form, must likewise *communicate* to the wet ball another portion of heat equal to its depression of temperature, which is hence maintained at a constant point. This analysis, however, involves the supposition, that the air conveys heat from bodies merely by its actual transfer. But having discovered that air transmits a certain share, at least, of the heat by a sort of pulsation, or internal tremor, depending on the quality of the surface from which the impression originates, it was requisite to examine anew the process of evaporation. The effect cannot be produced solely by the quickened recession of the contiguous portions of the ambient medium. The conterminous air must communicate heat to the humid surface also by pulsation; and hence the balance of temperature would be liable to incidental variations, if moisture, with its embodied heat, were not likewise abstracted by some corresponding process. And such is the harmonious adaptation of these elements: the discharge of vapour appears to be subject precisely to the same conditions as the emission of heat, and in both cases the proximity of a vitreous or a metallic surface produces effects which are entirely similar. Let two pieces of thin mirror-glass, or what is called Dutch plate, be selected, about four inches and a half square; and having applied a smooth coat of tinfoil, four inches square, to one of these, cover them both with a layer of the thinnest goldbeater's skin, which will adhere closely on being wetted; and after it has again become dry, cut it on each into an exact square of four inches and a quarter: now place the two glass plates horizontally in the opposite scales of a fine balance, and adjust them to an exact counterpoise: then, with a hair pencil, spread two grains of water over the surface of each pellicle: in a few seconds, the plate which is coated with tinfoil will preponderate, and after the former has lost all its moisture, this will be found to retain still three tenths of a grain. The proximity of the subjacent metal to the humid surface, therefore, impedes the process of evaporation, in the ratio of seventeen to twenty; the very same as, in like circumstances, had been ascertained to be the retardation of the efflux of heat. From this and other experiments, we learn, that some constant portion from a humid surface is always abstracted by the pulsation of the aërial medium. The steam exhaled, in uniting with the air, communicates to this elastic fluid a sudden dilatation, which will continue to propagate itself in successive waves.

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In further illustration of this matter, cover with a thin pellicle of goldbeater's skin both the balls of the *pyroscope*, or that form of the differential thermometer which has one ball naked and the other enamelled with gold or silver, and wet them equally. The coloured liquid will remain for several minutes stationary at the beginning of the scale, and will then mount slowly, perhaps ten or fifteen degrees. Evaporation had, therefore, produced the same cold or depression of temperature upon the surface of the metal as upon that of the glass; from the glass, however, it was more copious than from the metal, having left the former dry, while the latter still exhaled some portion of moisture. But this action soon ceased, and the liquid fell back to its former level. On applying another pellicle, the liquid continued longer stationary, and rose only about five degrees. With repeated pellicles a difference was perceptible in the time of drying the two balls, till the thickness amounted to the 600th part of an inch.

The mode of graduating it.

The method employed for the graduation of the hygrometer is not only very convenient, but susceptible of great accuracy. The instrument, with a temporary scale affixed to it, is introduced into a magazine of dry air, and compared with a standard then put in action. To procure the dryness of the included medium, a flat saucer of thirteen inches in diameter, and holding a body, about half an inch deep, of concentrated sulphuric acid, and set on a ground plate of glass or metal, is covered by a very large inverted receiver, containing more than 1500 cubic inches of air, and having at the top an opening of three inches wide, on which rests a smaller plate, with two or three hooks projecting down from it. The scale of the standard instrument was determined by suspending beside it, under the receiver, two delicate thermometers, one of which had its bulb coated with several folds of wet tissue paper. The descent of the coloured liquid of the hygrometer, corresponding to the difference of ten centesimal degrees of the parallel thermometers, was hence computed, and this length afterwards divided into an hundred equal parts, to form the standard degrees. To graduate any other instrument, it was only requisite to attach a scale of inches, and mark the simultaneous measures when a steady equilibrium had at last obtained. The space of half an hour is generally sufficient to bring this about. A simple proportion, therefore, discovers the length answering to an hundred millesimal degrees, from which the subdivisions of each particular scale are derived.

The condition of the atmosphere with respect to dryness is extremely variable. In our climate, the hygrometer will, during winter, mark from five to twenty-five degrees; but, in the summer months, it will generally range between fifteen and fifty-five degrees, and may even rise, on some particular days, as high as eighty or ninety degrees. On the continent of Europe, it maintains a much greater elevation; and in Upper India it has frequently stood at 160 degrees.

When the indication of the hygrometer does not exceed fifteen degrees, we are directed by our feelings to call the air damp; from thirty to forty degrees, we begin to reckon it dry; from fifty to sixty degrees, we should account it very dry; and from seventy degrees upwards, we might consider it as intensely dry. A room is not comfortable, or perhaps wholesome, if it has less than thirty degrees of dryness; but the atmosphere of a warm occupied apartment will commonly produce an effect of upwards of fifty degrees.

Its performance during frost.

But this hygrometer will perform its office even if it should be exposed to frost. The moisture spreads over the surface, and, imbibed into the coat of the papered ball, will first cool a few degrees below the freezing point, and

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then congeal quickly into a solid compound mass. The moment in which congelation begins, a portion of heat liberated in that act brings the ball back to the temperature of freezing; and the coloured liquor, in proportion to the coldness of the external air, starts up in the opposite stem, where it remains at the same height till the process of consolidation is completed. After the icy crust has been formed, evaporation again goes regularly forward; and if new portions of water be applied, the ice will, from the union of those repeated films, acquire a thickness sufficient to last for several days. The temperature of the frozen coat becomes lowered in proportion to the dryness of the atmosphere. The measure of heat deposited on the chill surface by the contact of the ambient air is then counterbalanced by the two distinct though conjoined measures of heat, abstracted in the successive acts of converting the exterior film of ice into water, and this water into steam; which transformations that minute portion must undergo before it can unite with its gaseous solvent. But the heat required for the melting of ice being about the seventh part of what is consumed in the vaporization of water, it follows that the hygrometer, when the surface of its sentient ball has become frozen, will, in like circumstances, sink more than before, by one degree in seven. This inference is entirely confirmed by observation. Suppose, in frosty weather, the hygrometer, placed on the outside of the window, to stand at twenty-eight degrees, it may continue for some considerable time at that point, until the congelation of its humidity commences; but after this change has been effected, and the equilibrium again restored, the instrument will now mark thirty-two degrees.

Estimate of the hygrometric degrees.

The theory of this hygrometer will enable us to determine, not only the relative, but even the absolute dryness of the air, or the quantity of moisture which it can absorb, by comparing the capacity of that solvent with the measure of heat required to convert a given portion of water into steam. To discover the capacity of air is, however, a problem of great difficulty, and it has not perhaps even yet been ascertained with much precision. It was formerly estimated, we are convinced, by far too high. Thus, Dr Crawford made it to be 1·85 times, or nearly double that of water. But, from several concurring observations, we should reckon the capacity of air to be only three tenth parts of that of water. But 600 centesimal degrees, or 6000 on the millesimal scale, being consumed in the vaporization of heat, this measure of heat would prove sufficient to raise an equal mass of air 20,000 millesimal degrees, or those 6000 degrees augmented in the ratio of ten to three. Now, at the state of equilibrium, the quantity of heat that each portion of the aërial medium deposites in touching the chill exhaling surface, or what answers to the depression of temperature which it suffers from this contact, must, as we have seen, be exactly equal to the opposite measure of heat abstracted by it in dissolving its corresponding share of moisture. Wherefore, at the temperature of the wet ball, atmospheric air would take up moisture amounting to the 20,000th part of its weight for each degree marked by the hygrometer. Thus, supposing the hygrometer to mark fifty degrees, the air would then require humidity equal to the 320th part of its weight for saturation at its reduced temperature. When the papered ball of the hygrometer is frozen, the degrees of this instrument must have their value increased by one seventh, so that each of them will now correspond to an absorption of moisture equal to the 17,000th part of the weight of the air.

But the value of those degrees becomes augmented in a much higher proportion if the hygrometer be immersed in hydrogen gas. This very dilute medium appears to have about eight times the capacity of common air, and the quantity of heat which under similar circumstances it will deposite on the evaporating surface must likewise, from the same principle of mutual balance, be eight times greater, and, consequently, each hygrometric degree will indicate an absorption of moisture equal in weight to the 750th part of the solvent. The energy of hydrogen gas is therefore scarcely less remarkable in dissolving moisture than in containing heat. Confined with a powerful absorbent substance, whilst common air marks eighty degrees of dryness, hydrogen gas will indicate seventy. This gas must, in similar circumstances, therefore, hold in solution seven times as much moisture as the atmospheric medium.

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Law of atmospheric solution.

To discover the precise law by which equal additions of heat augment the dryness of air, or its power to retain moisture, is a problem of great delicacy and importance. Two different modes were employed in that investigation, but which led to the same results. The one was, in a large close room, to bring an hygrometer, conjoined with a thermometer, successively near to a stove intensely heated, and to note the simultaneous indications of both instruments; or to employ two nice thermometers, placed beside each other, and having their bulbs covered respectively with dry and with wet cambric. By taking the mean of numerous observations, and interpolating the intermediate quantities, the law of aqueous solution in air was laboriously traced. But the other method of investigation appeared better adapted for the higher temperatures. A thin hollow ball of tin four inches in diameter, and having a very small neck, was neatly covered with linen, and being filled with water nearly boiling, and a thermometer inserted, it was hung likewise in a spacious close room, and the rate of its cooling carefully marked. The experiment was next repeated by suspending it to the end of a fine beam, and wetting with a hair pencil the surface of the linen, till brought in exact equipoise to some given weight in the opposite scale; ten grains being now taken out, the humid ball was allowed to rest against the point of a tapered glass tube, and the interval of time, with the corresponding diminution of temperature, observed, when it rose again to the position of equilibrium. The same operation was successively renewed; but, as the rapidity of the evaporation declined, five, and afterwards two, grains only were, at each trial, withdrawn from the scale. From such a series of facts, it was easy to estimate the quantities of moisture which the same air will dissolve at different temperatures, and also the corresponding measures of heat expended in the process of solution.

By connecting the range of observations, it would appear that air has its dryness doubled at each rise of temperature, answering to 15 centesimal degrees. Thus, at the freezing point, air is capable of holding a portion of moisture represented by 100 degrees of the hygrometer; at the temperature of 15 centigrade, it could contain 200 such parts; at that of 30, it might dissolve 400; and, at 45 on the same scale, 800. Or, if we reckon by Fahrenheit's divisions, air absolutely humid holds, at the limit of congelation, the hundred and sixtieth part of its weight of moisture; at the temperature of 59 degrees, the eightieth part; at that of 86 degrees, the fortieth part; at that of 113 degrees, the twentieth part; and at that of 140 degrees, the tenth part. While the temperature, therefore, advances uniformly in arithmetical progression, the dissolving power which this communicates to the air mounts with the accelerating rapidity of a geometrical series.

It hence follows, that, whatever be the actual condition of a mass of air, there must always exist some temperature at which it would become perfectly damp, as M. Leroi had first advanced. Nor is it difficult, from what has been already stated, to determine this *dewing point* in any given case. Thus, suppose the hygrometer to mark 52, while its wet ball has a temperature of 20 centesimal degrees, or 68 by Fahrenheit; the dissolving power of air at this tem-

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perature being 252, its distance from absolute humidity will therefore be 200, which is the measure of solution answering to 15 centesimal degrees, or 59 by Fahrenheit. The same air would consequently, at the depressed temperature of 59 degrees, shrink into a state of absolute saturation; and if cooled lower, it would even deposite a portion of its combined moisture, losing the eightieth part of its weight at the verge of freezing.

Annexed is a small table of the solvent power of air, from the temperature of 15 centesimal degrees below zero to 44 above it, or from — 5° of Fahrenheit's scale to 111°·2.

Quantities of Moisture dissolved in Atmospheric Air at different Temperatures by the Centesimal Scale.

Temp.	Moist.	Temp.	Moist.	Temp.	Moist.	Temp.	Moist.
°		°		°		°	
— 15	50·0	0	100·0	15	200·0	30	400·0
— 14	52·4	1	104·7	16	209·5	31	418·9
— 13	54·9	2	109·7	17	219·4	32	438·7
— 12	57·4	3	114·9	18	229·7	33	459·5
— 11	60·1	4	120·3	19	240·6	34	481·2
— 10	63·0	5	126·0	20	252·0	35	504·0
— 9	66·0	6	132·0	21	263·9	36	527·8
— 8	69·1	7	138·2	22	276·4	37	552·8
— 7	72·4	8	144·7	23	289·5	38	578·9
— 6	75·8	9	151·6	24	303·1	39	606·3
— 5	79·4	10	158·7	25	317·5	40	635·0
— 4	83·1	11	166·2	26	332·5	41	665·0
— 3	87·1	12	174·1	27	348·2	42	696·4
— 2	91·2	13	182·3	28	364·7	43	729·4
— 1	95·5	14	191·0	29	381·9	44	763·9

These temperatures, and the corresponding quantities of moisture dissolved, may be represented by the abscissæ and ordinates of the logarithmic curve, as in fig. 8, Plate CCCLV., where some of the principal terms are marked.

The influence of warmth in augmenting the dryness of the air, or its disposition to absorb moisture, affords also the most satisfactory explication of the singular fact already noticed. If two equal surfaces of water be exposed in the same situation, the one in a shallow and the other in a deep vessel of metal or porcelain, the latter is always found, after a certain interval of time, to have suffered, contrary to what we might expect, more waste by evaporation than the former. Amidst all the changes that happen in the condition of the ambient medium, the shallow pan must necessarily receive, more completely than the deeper vessel, the chilling impressions of evaporation, since it exposes a smaller extent of dry surface to be partly heated up again by the contact of the air. The larger mass being, therefore, kept invariably warmer than the other, must in consequence support a more copious exhalation.

Correction of the hygrometer.

From the principles which have been explained, it likewise results that the hygrometer does not indicate the actual dryness of the air, but only the dryness which it retains after being reduced to the temperature of the humid ball. The real condition of the medium, however, could easily be determined, from the gradations already ascertained in the power of solution. Suppose, for example, that the hygrometer should mark 42 degrees, while the thermometer stands at 16 centigrade; the moist surface has therefore the temperature of 11·8 centigrade, at which the dissolving energy is less by 37 degrees than at 16 centigrade; and hence the total dryness of the air, at its former temperature, amounted to 79 degrees. The following table will greatly facilitate such reductions. It is computed for as wide a range of dryness and temperature as will probably occur in any climate.

Correction of the Hygrometer, and Position of the Point of Saturation at Different Centesimal Temperatures.

	— 15°		— 14°		— 13°		— 12°		— 11°		
Hyg.	Dryness.	Point Sat.	Dryness.	Point Sat.	Dryness.	Point Sat.	Dryness.	Point Sat.	Dryness.	Point Sat.	Hyg.
10	12	— 21·0	12	— 19·5	12	— 18·3	13	— 17·8	13	— 16·3	10
20	24	— 29·2	24	— 27·6	25	— 26·1	25	— 24·7	25	— 23·2	20
30	36	— 42·7	36	— 39·8	37	— 37·2	37	— 35·0	38	— 32·9	30
	— 10°		— 9°		— 8°		— 7°		— 6°		
10	13	— 15·0	13	— 13·8	13	— 12·5	13	— 11·4	13	— 10·0	10
20	26	— 21·5	26	— 19·8	26	— 18·2	26	— 16·8	27	— 15·4	20
30	38	— 30·1	39	— 28·3	39	— 26·1	39	— 24·4	40	— 22·2	30
	— 5°		— 4°		— 3°		— 2°		— 1°		
10	14	— 9·3	14	— 7·9	14	— 6·8	14	— 5·6	14	— 4·5	10
20	27	— 14·0	27	— 12·6	28	— 11·3	28	— 9·9	28	— 8·6	20
30	40	— 20·3	41	— 18·8	41	— 16·9	42	— 15·2	42	— 13·7	30
40	53	— 29·2	54	— 26·9	55	— 24·6	55	— 22·2	56	— 20·4	40
	0°		1°		2°		3°		4°		
10	15	— 3·4	15	— 2·3	15	— 1·2	15	0·0	15	1·0	10
20	29	— 7·4	29	— 6·1	30	— 4·8	30	— 3·6	31	— 2·3	20
30	43	— 12·2	43	— 10·6	44	— 9·1	45	— 7·7	45	— 6·3	30
40	57	— 18·2	58	— 16·3	59	— 14·5	59	— 12·7	60	— 11·0	40

Correction of Hygrometer, &c.—Continued.

	5°		6°		7°		8°		9°		
Hyg.	Dry-ness.	Point Sat.	Dry-ness.	Point Sat.	Dry-ness.	Point Sat.	Dry-ness.	Point Sat.	Dry-ness.	Point Sat.	Hyg.
10	16	2·1	16	3·1	16	4·3	16	5·4	17	6·5	10
20	31	— 1·1	32	0·0	32	1·3	33	2·4	33	3·6	20
30	46	— 4·9	47	— 3·6	48	— 2·2	49	— 0·9	50	0·4	30
40	61	— 9·4	62	— 7·8	63	— 6·3	64	— 4·7	66	— 3·3	40
50	76	— 15·0	77	— 13·0	79	— 11·1	80	— 9·4	81	— 7·6	50
	10°		11°		12°		13°		14°		
10	17	7·5	18	8·6	18	9·6	18	10·7	19	11·8	10
20	34	4·8	35	5·9	35	7·1	36	8·2	37	9·4	20
30	50	1·9	52	3·0	53	4·3	54	5·5	55	6·7	30
40	67	— 1·8	68	— 0·4	69	1·0	71	2·4	72	3·7	40
50	83	— 5·9	84	— 4·3	86	— 2·7	88	— 1·1	89	0·4	50
60	98	— 11·0	100	— 9·0	102	— 7·1	104	— 5·4	106	— 3·7	60
	15°		16°		17°		18°		19°		
10	19	12·9	20	13·9	20	15·0	20	16·0	21	17·0	10
20	38	10·5	39	11·6	39	12·7	40	13·8	41	14·9	20
30	56	7·9	57	9·1	58	10·3	60	11·5	61	12·7	30
40	74	5·0	75	6·4	77	7·6	79	8·9	81	10·2	40
50	91	1·8	93	3·3	95	4·7	97	6·0	100	7·4	50
60	108	— 1·8	111	— 0·2	113	1·3	116	2·8	118	4·4	60
70	125	— 6·3	128	— 4·5	131	— 2·6	134	— 0·8	136	0·9	70
80	142	— 11·8	145	— 9·5	148	— 7·2	151	— 5·2	154	— 3·2	80
	20°		21°		22°		23°		24°		
10	21	18·1	22	19·1	22	20·1	23	21·2	24	22·2	10
20	42	16·0	43	17·1	44	18·2	46	19·3	47	20·4	20
30	63	13·8	64	15·0	66	16·1	68	17·3	69	18·4	30
40	83	11·4	84	12·6	87	13·8	89	15·0	91	16·2	40
50	102	8·8	104	10·1	107	11·4	110	12·7	112	13·9	50
60	121	6·1	124	7·4	127	8·7	130	10·2	133	11·5	60
70	140	2·5	143	4·1	146	5·7	150	7·2	154	8·7	70
80	158	— 1·3	162	0·5	165	2·3	169	4·0	174	5·6	80
90	176	— 5·9	180	— 3·8	184	— 1·8	188	0·2	193	2·0	90
100	193	— 11·5	198	— 9·0	202	— 6·5	207	— 4·3	212	— 2·0	100
	25°		26°		27°		28°		29°		
10	24	23·3	25	24·3	26	25·3	26	26·4	27	27·4	10
20	48	21·4	49	22·5	51	23·6	52	24·7	54	25·7	20
30	71	19·5	73	20·6	75	21·7	77	22·8	79	23·9	30
40	94	17·4	96	18·6	99	19·8	102	21·0	104	22·1	40
50	116	15·2	119	16·5	122	17·7	125	18·9	129	20·1	50
60	137	12·8	141	14·1	144	15·4	148	16·7	152	18·1	60
70	158	10·1	162	11·6	166	13·0	171	14·3	175	15·7	70
80	178	7·2	183	8·7	188	10·3	193	11·7	198	13·2	80
90	198	3·9	203	5·6	209	7·2	214	8·9	220	10·4	90
100	218	0·0	223	2·0	229	3·8	235	5·6	241	7·4	100
110	237	— 4·5	242	— 2·3	249	— 0·1	255	2·0	262	3·9	110
120	255	— 10·2	261	— 7·4	268	— 4·8	275	— 2·4	282	— 0·1	120

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Correction of Hygrometer, &c.—continued.

	30°		31°		32°		33°		34°		
Hyg.	Dryness.	Point Sat.	Dryness.	Point Sat.	Dryness.	Point Sat.	Dryness.	Point Sat.	Dryness.	Point Sat.	Hyg.
10	28	28·4	29	29·5	30	30·5	31	31·5	32	32·5	10
20	55	26·8	57	27·8	59	28·9	61	30·0	63	31·0	20
30	82	25·0	84	26·1	87	27·2	90	28·3	92	29·4	30
40	108	23·2	111	24·4	114	25·5	118	26·6	121	27·7	40
50	133	21·3	136	22·5	141	23·7	145	24·9	149	26·0	50
60	157	19·3	161	20·5	166	21·7	171	22·9	177	24·1	60
70	181	17·0	186	18·3	191	19·6	197	20·9	203	22·1	70
80	204	14·6	209	16·0	216	17·4	222	18·7	229	20·0	80
90	226	12·0	233	13·5	239	15·0	246	16·4	254	17·8	90
100	248	9·1	255	10·7	262	12·3	270	13·8	278	15·3	100
110	269	5·8	277	7·6	285	9·3	293	11·0	302	12·6	110
120	290	2·0	298	4·1	307	6·0	316	7·9	325	9·7	120

	35°		36°		37°		38°		39°		
10	33	33·6	34	34·6	35	35·6	36	36·6	37	37·6	10
20	65	32·0	67	33·1	69	34·1	71	35·2	73	36·2	20
30	95	30·5	98	31·5	102	32·6	105	33·7	108	34·7	30
40	125	28·9	129	30·0	133	31·0	138	32·1	142	33·2	40
50	154	27·1	159	28·2	164	29·4	169	30·5	175	31·6	50
60	182	25·3	188	26·5	194	27·7	200	28·8	207	30·0	60
70	209	23·4	216	24·6	223	25·8	230	27·0	238	28·2	70
80	236	21·3	243	22·6	251	23·9	259	25·2	267	26·4	80
90	262	19·2	270	20·5	278	21·9	287	23·2	296	24·5	90
100	287	16·8	295	18·3	305	19·7	314	21·1	324	22·4	100
110	311	14·2	320	15·8	330	17·3	341	18·8	352	20·2	110
120	335	11·4	345	13·1	355	14·7	366	16·3	378	17·9	120
130	358	8·3	368	10·1	380	11·9	391	13·6	404	15·3	130
140	380	4·7	391	6·7	403	8·7	416	10·6	429	12·4	140

	40°		41°		42°		43°		44°		
10	39	38·6	40	39·7	41	40·7	43	41·7	44	42·7	10
20	76	37·2	79	38·3	81	39·3	84	40·3	87	41·3	20
30	112	35·8	116	36·9	120	37·9	124	39·0	129	40·0	30
40	147	34·3	152	35·4	158	36·5	163	37·6	169	38·7	40
50	181	32·7	187	33·8	194	34·9	201	36·0	208	37·1	50
60	214	31·1	221	32·3	229	33·4	237	34·5	245	35·6	60
70	246	29·4	254	30·6	262	31·8	272	32·9	281	34·1	70
80	276	27·6	286	28·9	295	30·1	305	31·3	316	32·4	80
90	306	25·8	316	27·1	327	28·4	338	29·6	350	30·7	90
100	335	23·7	346	25·1	358	26·4	370	27·7	383	29·0	100
110	363	21·6	375	23·0	388	24·4	401	25·8	414	27·1	110
120	390	19·4	403	20·8	416	22·2	430	23·7	445	25·1	120
130	417	16·9	430	18·5	444	20·0	459	21·5	475	23·0	130
140	443	14·2	457	15·9	472	17·5	487	19·1	504	20·7	140
150	468	11·2	483	13·0	498	14·8	515	16·5	532	18·2	150
160	492	7·8	508	9·8	524	11·8	541	13·7	559	15·5	160

Quantity of moisture held in the air.

We may compute, that a cubic mass of air 40 inches every way, or a little more than the standard of French measures, and of the ordinary density, weighs 20,000 grains. The table now given exhibits, therefore, in grains, the weight of moisture which a metrical cube of air is capable of holding at different temperatures. Thus, at 20 degrees, which corresponds to 68 degrees of Fahrenheit, this body of air could retain 252 grains of humidity. But if a larger scale be preferred, the same numbers will express, in pounds troy, the quantity of water required to saturate a perfectly dry mass of air constituting a cube of twenty yards in every dimension.

It is remarkable how small a portion of the aqueous element is at any time suspended in the atmosphere. Reckoning the mean temperature over the surface of the globe to be nineteen centesimal degrees, the air could only hold 240·6 parts of humidity for 20,000 times its whole weight; but this weight is nearly the same as that of a column of water of 400 inches in altitude, and hence, if the atmosphere, from a state of absolute dampness, were to pass into that of extreme dryness, and discharge the whole of its watery store, it would form a sheet of 4·812 inches, or somewhat less than five inches in depth. To furnish a sufficient supply of rain, the air must therefore undergo

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very frequent changes from dryness to humidity in the course of the year.

Determined by experiment.

But it was requisite to subject theory to the test of accurate experiment. For this purpose a globe or glass balloon was procured, of very large dimensions, containing nearly 4000 cubic inches, terminated by a neck of about three inches wide, having its mouth ground flat. The balloon was supported from the floor by a light circular stand or rim, and a round piece of plate glass perforated through the centre by a hole of about the twentieth part of an inch in diameter, through which passed a slender silver wire suspended from the end of a fine beam placed on the table. This wire was fastened to the top of the scale of a delicate hygrometer, from the lower part of which hung a bit of wet paper nearly three inches in diameter. The whole was balanced by a counterpoise in the opposite scale, so that the instrument occupied the middle of the balloon. As the moisture gradually evaporated from the wet ball of the hygrometer, and still more from the larger surface of the paper attached below it, a loss of weight became visible, while the ascent of the coloured liquid in its tube indicated the corresponding diminution of the dryness of the included air. The progress of humefaction was observed from fifty to ten degrees of the hygrometer, after each successive grain of water, amounting in all to five, had exhaled and dispersed itself through the medium. Having rectified the hygrometric degrees according to the principle already explained, it was easy to compare them with the weight of the whole mass of air contained within the balloon. The conclusions were perhaps as satisfactory as such a nice and fugacious inquiry will admit; and if they be not absolutely correct, they must, at least, approximate very nearly to the truth.

Modification of the table.

The table given above is in strictness applicable to air only of the ordinary density. Since this fluid has its capacity for heat enlarged by rarefaction, the same depression of temperature must intimate a proportional augmentation of dryness. Thus, for air at the elevation of three miles and a half, and consequently twice as rare as at the surface, it would be requisite to add the sixteenth part to the numbers in the first column. For the lower altitudes, the correction will be, to multiply those numbers by triple the height in feet, and cut off six decimal places. Thus, suppose, while the thermometer stood at twenty-eight centesimal degrees, that the hygrometer marked 110° on the plains of Mexico, at the elevation of 8000 feet above the level of the sea; then $3 \times 8000 \times 255 = 6120000$, which, being divided by a million, gives 6 to be added to 255, increasing the actual dryness to 261°. In most cases, therefore, this modification may be neglected.

But, in estimating the distance of the point of saturation in rarefied air, a greater correction will be required. The solvent power of that medium is extended about fifty hygrometric degrees each time it has its rarefaction doubled. Hence it may be calculated that our atmosphere would, at the same temperature, become a degree drier for every 360 feet of ascent. Thus, on the preceding supposition, the air on the plain of Mexico would have its distance from the point of saturation enlarged $22\frac{1}{2}$ degrees, its whole range being thus $283\frac{1}{2}$ degrees.

Different applications of the hygrometer.

If the papered ball of an hygrometer be suffered to become dry, the instrument, even in that state, will mark, though for a short time only, the different condition of the media into which it is transported. Thus, the air of a room being supposed to have fifty degrees of dryness, on carrying the quiescent hygrometer into another apartment of seventy degrees, the column of liquor will fall near twenty degrees, from the renewed evaporation of that portion of moisture which had still adhered to the coats of paper. But if the same instrument were carried into an apartment of only thirty degrees of dryness, the coloured liquor would actually rise near twenty degrees above the beginning of the scale, the paper now attracting the excess of humidity from the air. This vapour, in combining with it, passes into the state of water, and therefore evolves a corresponding share of heat. The equilibrium, however, unless the coats of paper have a considerable thickness, is again restored in a very few minutes.

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Those changes are most readily perceived on immersing the quiescent hygrometer alternately in two receivers containing air drier and damper than that of the room. If a pyroscope, having both its balls covered with goldbeater's skin, be treated in the same way, it will indicate an effect, though momentary indeed, of a similar kind; for, in air which is drier, the pellicle of the naked ball will throw off its moisture more freely than that of the gilt ball; and in damper air it will, on the contrary, imbibe the surplus humidity with greater eagerness, thus losing some portion of heat in the one process, and gaining a minute accession in the other. The quantity of moisture concerned in producing such fleeting alterations may not exceed the thousandth part of a grain.

If a large receiver, having a delicate hygrometer suspended within it, be placed on a brass plate and over a metal cup containing some water, the included air will, from the solution of the moisture, become gradually damper, and this progressive change is marked by the instrument. Yet the mass of air will never reach its term of absolute humidity, and before the hygrometer points at five degrees, the inside of the receiver appears covered with dew. While the humefying process, therefore, still goes on, the close attraction of the glass continually robs the contiguous air of a portion of its moisture, so that a kind of perpetual distillation is maintained through the aërial medium, the vapour successively formed being again condensed on the vitreous surface. But if, instead of the receiver, there be substituted a vessel formed of polished metal, the confined air will pass through every possible degree of humidity, and the hygrometer will, after some interval, arrive at the beginning of its scale.

The contrasted properties of a vitreous and a metallic surface, in attracting and repelling moisture, may be shown still more easily. In clear calm weather let a drinking-glass and a silver cup be placed empty near the ground on the approach of evening, and, as the dampness begins to prevail, the glass will become insensibly obscured, and next wetted with profuse dew, before the metal has yet betrayed any traces of humidity. The effect is, indeed, augmented by the cold pulses darted from the sky, which act more powerfully on the glass than on the metal.

Its practical utility.

The hygrometer is an instrument of the greatest utility, not only in meteorological observations, but in aiding domestic economy, in regulating many processes of art, and in directing the purchase and selection of various articles of produce. It will detect, for instance, the dampness of an apartment, and discover the condition of a magazine, of an hospital, or of a sick ward. Most warehouses require to be kept at a certain point of dryness, which is higher or lower according to the purposes for which they are designed. The printing of linen and cotton is carried on in very dry rooms; but the operations of spinning and weaving succeed best in air which rather inclines to dampness.

The manufacturer is at present entirely guided by observing the effects produced by stoves, and hence the goods are often shrivelled or otherwise injured before he can discern any alteration in the state of the medium. Wool and corn have their weight augmented sometimes as much as 10 or even 15 per cent. by the presence of moisture. But the condition of these commodities could be nicely and readily examined, by heaping them over a small wired cage, within which an hygrometer is placed.

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Atmometer.

V. The Atmometer.[1]—This instrument is an useful auxiliary, and might with some attention serve as a substitute of the hygrometer. It does not mark the mere dryness of the air, but it measures the quantity of moisture exhaled from a humid surface in a given time. The atmometer consists of a thin ball of porous earthenware, two or three inches in diameter, with a small neck, to which is firmly cemented a long and rather wide glass tube, bearing divisions, each of them corresponding to an internal annular section, equal to a film of liquid that would cover the outer surface of the ball to the thickness of the thousandth part of an inch. (Fig. 1, Plate CCCLV.) The divisions are marked by portions of quicksilver introduced, ascertained by a simple calculation, and they are numbered downwards to the extent of 100 to 200; to the top of the tube is fitted a brass cap, having a collar of leather, and which, after the cavity has been filled with distilled water, is screwed tight. The outside of the ball being now wiped dry, the instrument is suspended out of doors, exposed to the free access of the air. In this state of action the humidity transudes through the porous substance just as fast as it evaporates from the external surface, and this waste is measured by the corresponding descent of the water in the stem.

Quantity of moisture exhaled.

If the atmometer had its ball perfectly screened from the agitation of wind, its indications would be proportional to the dryness of the air at the lowered temperature of the humid surface; and the quantity of evaporation every hour, as expressed in thousandth parts of an inch, would, when multiplied by twenty, give the hygrometric measure. For example, in this climate, the mean dryness in winter being reckoned 15°, and in summer 40°, the daily exhalation from a sheltered spot must in winter form a thickness of ·018, and amount in summer to ·048 decimal parts of an inch. Suppose a pool for the supply of a navigable canal exposed a surface equal to ten English acres, and that the atmometer sank eighty parts during the lapse of twenty-four hours; the quantity of water exhaled in that time would be

$$\frac{80}{12000} \times 660 \times 66 \times 10,$$ or 2904 cubic feet, which corresponds to the weight of 81 tons.

Velocity of wind.

The dissipation of moisture is much accelerated by the agency of sweeping winds, the effect being sometimes augmented five or even ten times. In general, this augmentation is proportional, as in the case of cooling, to the swiftness of the wind, the action of still air itself being reckoned equal to that produced by a celerity of eight miles each hour. Hence the velocity of wind is easily computed, from a comparison of the indications of a hygrometer with an atmometer, or of a sheltered with those of an exposed atmometer. Thus, suppose the hygrometer to mark 40 degrees, or the column of water in a sheltered atmometer to subside at the rate of two divisions every hour, while in one exposed to the current the descent is twelve divisions; then as two is to ten, the superadded effect of the wind, so is eight to forty miles, the distance through which it has travelled in that time.

Utility of the atmometer.

The atmometer is an instrument evidently of extensive application, and of great utility in practice. To ascertain with accuracy and readiness the quantity of evaporation from any surface in a given time, it is an important acquisition, not only in meteorology, but in agriculture, and the various arts and manufactures. The rate of exhalation from the surface of the ground is scarcely of less consequence than the fall of rain, and a knowledge of it might often direct the farmer advantageously in his operations. On the rapid dispersion of moisture depends the efficacy of drying-houses, which are too frequently constructed most unskilfully, or on very mistaken principles.

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It is obvious, that though the atmometer should be exposed to the free air, it must be sheltered from rain, which, by wetting the ball, would derange the proper action of the instrument. This could easily be done, by fixing a small canopy over it; or, in the case of drifting showers, to have a sort of shelved open screen, like Venetian blinds, turned by the wind. The only objection to this atmometer is, that it cannot be used during intense frost, since the expansion of the included water, by a sudden congelation, might burst the ball and even the tube. But the instrument could still be made to act in another way: Let it be emptied, and a certain portion of the water, measured in the stem, be spread over the outside of the ball, by successive layers, to form a coat of ice. The time is to be noted when the whole of this crust has disappeared; or if any portion should remain, it may be deducted from the whole, and thus the hourly quantity of evaporation ascertained.

Construction of the photometer.

VI. Photometer.[2]—This instrument, which was contrived to indicate the power of illumination, by the slight elevation of temperature which it occasions, has been shortly noticed in the article Climate. It consists of a differential thermometer, having one of its balls diaphanous, and the other coated with china ink, or rather blown of deep-black enamel. (See fig. 17 and 18, Plate CCCLIV.) The rays which fall on the clear ball pass through it, without suffering obstruction; but those which strike the dark ball are stopt and absorbed at its surface, where, assuming a latent form, they act as heat. This heat will continue to accumulate, till its farther increase comes to be counterbalanced by an opposite dispersion, caused by the rise of temperature which the ball has come to acquire. At the point of equilibrium, therefore, the constant accessions of heat derived from the action of the incident light are exactly equalled by the corresponding portions of it again abstracted in the subsequent process of cooling. But, in still air, the rate of cooling is, within moderate limits, proportioned to the excess of the temperature of the heated surface above that of the surrounding medium. Hence the space through which the coloured liquid sinks in the stem will measure the momentary impressions of light, or its actual intensity. To prevent any extraneous agitation of the air from accelerating the discharge of heat from the black ball, and thereby diminishing the quantity of aggregate effect, the instrument is always sheltered, and more especially out of doors, by a thin glass case. The addition of this translucid case is quite indispensable. It not only precludes all irregular action, but maintains, around the sentient part of the instrument, an atmosphere of perpetual calm. Under the same force of incident light, the temperature of the black ball must still rise to the same height above that of its encircling medium. The case will evidently have some influence to confine the heat actually received, and hence to warm up the internal air. Wherefore, corresponding to this excess, the black ball will acquire a farther elevation of temperature; but the clear ball, being immersed in the same fluid, must experience a similar effect, which will exactly counterbalance the former. The difference of temperature between the opposite balls thus continues unaltered; and neither has the size or the shape of the case, nor the variable state of the exterior atmosphere with respect to rest or agitation, any sensible influence to derange or modify the results exhibited by this delicate instrument.

Theory of its operation.

The photometer has, like the hygrometer, two general forms; the *stationary*, represented by fig. 15, and the

[1] From ἀτμος, *exhalation* or *vapour*, and μετρον, *a measure*.

[2] From φως, *light*, and μετρον, *a measure*.

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portable, delineated in fig. 18. But they are both of them easily transported from one place to another. Their glass cases can be screwed off, and the former instrument, being cemented into a small slip of brass, which slides with a spring into the bottom, may be packed separately, if required, while the latter is protected by an external wooden case, in which it is carried in the pocket as safely as a pencil. This case, if screwed below, serves also as a handle to hold the photometer in a vertical position out of doors.

Its use.

The photometer, placed in open air, exhibits distinctly the progress of illumination from the morning's dawn to the full vigour of noon, and thence its gradual decline till evening has spread her mantle; it marks the growth of light from the winter solstice to the height of summer, and its subsequent decay through the dusky shades of autumn; and it enables us to compare, with numerical accuracy, the brightness of different countries, the brilliant sky of Italy, for instance, with the murky atmosphere of Holland.

In this climate, the direct impression of the sun about midsummer amounts to about 90 degrees; but it regularly declines as his rays become more oblique. The greatest force of the solar beams with us in the depth of winter reaches only to 25 degrees. At the altitude of 17 degrees, it is already reduced to one half; and at 3 degrees above the horizon, the whole effect exceeds not one millesimal degree.

Light of the sun.

The quantity of indirect light reflected from the sky, though extremely fluctuating in our climate, is often very considerable. It may be estimated at 30 or 40 degrees in summer, and 10 or 15 in winter. This secondary light is most powerful when the sky is overspread with thin fleecy clouds; it is feeblest, either when the rays are obstructed by a mass of congregated vapours, or when the atmosphere is clear and of a deep azure tint. On the lofty summits of the Alps or Andes, the photometer, screened from the sun, and only exposed to the dark hue of the broad expanse, would indicate a very small effect. During the solar eclipse which took place on the 7th of September 1820, the sky being completely overclouded, it showed, both before and after the passage of the moon's disc, only 12 degrees of light; but when the obscuration was the greatest, it marked not more than a single degree.

Light of the sky.

Various applications of the photometer.

The delicacy of this instrument renders it a valuable auxiliary in various scientific inquiries. It ascertains the diminution which the rays of light suffer in reflection, and during their passage through different transparent substances. By combining it with the transferrer of an air-pump, it likewise detects the comparative powers for conducting heat of the several gases, whether in their ordinary state, or when variously attenuated or condensed. Hence we learn, that air expanded 256 times conducts heat nearly twice as slow, or in the ratio of 7 to 13; but that hydrogen gas transfers it with more than redoubled celerity, or in the ratio of 9 to 4. But the photometer will measure also the conducting powers of different liquids. It is only wanted to remove the case, and plunge the instrument erect in a wide metallic vessel, bright on the outside, but blackened within, containing the liquid to be examined, and exposed to the sun's rays. In this way, it was found that water, which conveys heat about 30 times faster than air of the mean temperature of our climate, transfuses it with still greater rapidity if warmed to a higher pitch. If the photometer, enclosed within its case, be immersed under the surface of water, the impression of the light will be much stronger than when the balls were encircled by the actual contact of this liquid. Yet will the effect be less than if the case had been surrounded externally by a body of air instead of water, which, by its powerful action in drawing off the accumulated heat, hastens the transmission of it through the internal medium, and reduces the elevation of the temperature of the black ball to nearly one third part.

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From observations made with this instrument, we likewise discover that, in the clearest and most serene sky, one half only of the sun's light, sloping at an angle of 25°, will reach the ground; and that at an angle of 15°, the proportion is reduced to one third; but with an obliquity of 5°, the length of track being then extended ten times, one twentieth part only of the whole incident light can reach the surface. When the sun has approached within a degree of the horizon, and his rays now traverse a track of air equal in weight to a column of about 905 feet of water, no more than the 212th part of them can penetrate to the ground.

The photometer discovers the relative density of different artificial lights, and even contrasts their force of illumination with that of the solar rays. It may be mentioned as a curious inference, that the light emitted from the sun is 12,000 times more powerful than the flame of a wax-candle; or that, if a portion of the luminous solar matter, rather less than an inch in diameter, were transported to our planet, it would throw forth a blaze of light equal to the effect of 12,000 candles.

To compare the illumination of candles or lamps, and of the flame of coal or oil gas, the best form of the photometer is that of fig. 15, Plate CCCLIV., guarded both in front and behind by a pair of thin spreading plates of mica, set parallel at the mutual interval of about half an inch. It may be sufficient to notice at present, that the flame of coal-gas has more than triple the brilliancy of that of a wax-candle.

A photometer of the branched form is easily adapted to measure the diminution which light suffers in penetrating through a body of water. The scale may then be shortened, and the balls enlarged. A bottom of lead is turned to receive the instrument, with its case, which are cemented to it. Thus loaded, the photometer is suspended vertically by cross silk threads, to which a cord of some definite length is attached, terminating by a small bladder. The sky being clear, and the sun shining bright, the instrument is, by the help of a long pole, stretched from the side of a boat, held a few minutes suspended about four inches below the surface of the water, and then drawn up, and the number of degrees marked. When the direct action of the solar rays amounted to 90 photometric degrees, their enfeebled influence on the instrument, while thus encompassed externally by a dense chilling body of water, was commonly found to be reduced to 32 degrees. From this point, therefore, the subsequent diminution, occasioned by the descent of the instrument, was computed. The photometer, being let down, was left to float near a quarter of an hour at the depth of perhaps three or six fathoms. On drawing it up, the diminished action of the light, occasioned by the length of oblique passage, was at once perceived.

From experiments performed in this way last summer, it follows that half of the incident light which might pass through a field of air of the ordinary density and $15\frac{1}{2}$ miles of extent, would penetrate only to the perpendicular depth of 15 feet in the clearest sea-water, which is, therefore, 5400 times less diaphanous than the atmospheric medium. The light is hence diminished four times for every five fathoms of vertical descent; and, consequently, the 64th part only could reach to the depth of 15 fathoms. Supposing the bottom, then, to consist of a clear white sand, the portion of light reflected, and sent back to the surface, would be attenuated more than 64×64, or 4096 times, and would therefore hardly be perceptible to the most acute eye. But the water of shallow lakes, though not apparently turbid, betrays a still greater opacity, insomuch that the perpendicular light was diminished one half in

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descending only through the space of six feet in Loch Leven, or even two feet in a fine artificial sheet of water at Raith, near Kirkaldy. These results, however, are to be considered as mere approximations, the state of the weather having been very unfavourable for such experiments.

It would be easy, by a small modification, to adapt the photometer as a diaphanometer, for measuring the comparative transparency of different collections of water. The black and the clear ball might be blown larger than usual, and the instrument covered with two thin parallel cases of glass, separated by an interval of about three eighths of an inch. The transparency of a lake, or of the sea, would be inversely as the length of passage traversed by the light, when it had suffered a proportional diminution of intensity.

Construction of the æthrioscope.

VII. Æthrioscope.[1]—Such is the name of another very delicate modification of the differential thermometer, intended to measure those frigorific impressions which are showered incessantly from the distant sky. The history of this invention, and of its progressive improvement, has been already given in this work under the article Climate. For about two years few good observations were added, owing to the prevalence of very cloudy and windy weather. The chief object, then, was to render the æthrioscope more portable, in the hope of obtaining, through it, some correct information regarding the state of the atmosphere in other quarters of the globe. The upper ball is now scarcely half an inch in diameter; but to compensate for this diminution, the lower ball has a diameter of about four fifths of an inch. The tube, which exceeds not four inches in length, has its bore contracted, a little above its junction, to the very short cylindrical cavity that holds the coloured liquor. This simple contrivance, augmenting greatly the capillary action, prevents the descent of the column into the ball from any sudden change of temperature, while it only retards the motion of the fluid, without affecting the accuracy of its play. Fig. 10, Plate CCCLV. represents the instrument in this abridged form, and fig. 11 shows the way of packing it, the bottom being merely screwed to the top of the case. The only precaution needed is, not to shake the æthrioscope, or invert it; and as it takes very little room, it may easily be carried by the traveller in his pocket.

Theory of this instrument.

In ordinary cases, the hot or cold pulses propagated through the air only assist the energy of the transfer of the different portions of the fluid in promoting an equilibrium of temperature. But the æthrioscope proves that those pulses are incessantly forwarding such a balance, even while the mere transfer and commixture of the medium would not contribute to the effect. In the article Climate, it was shown that the rapid interchange which takes place between the higher and lower strata of the atmosphere maintains an equal distribution in the *quantity*, and not in the *intensity*, of heat. Since air has its capacity for heat increased by rarefaction, it must, with the same igneous infusion, indicate a proportionally depressed temperature. But this inequality of temperature, resulting from the internal commotion produced by the sun's rays acting more powerfully near the surface of the earth, is partly corrected by the influence of the cold or hot pulses which are at all times darted, and in every direction, unless obstructed or absorbed by the interposition of the clouds. While the cold pulses from the upper strata of the atmosphere are constantly chilling the lower strata, the warm pulses again from below are exerted in warming the higher regions. In most cases this mutual influence, indeed, is comparatively feeble; but if the rays of the sun were withdrawn for any considerable time, a great progress would be made by such a mutual interchange of the pulsations towards an equality of temperature through the mass of atmosphere. The lowest strata would become unusually colder, whilst the highest regions would grow warmer, and sparkle with augmented clearness and lustre. Such are some of the effects of the long protracted nights within the arctic circle.

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Its inverted form.

Much yet remains to be explored in the higher strata of our atmosphere. If the differential thermometer, included within the æthrioscope, had its position reversed, that instrument would become adapted to measure the hot pulses which are no doubt shot incessantly upwards with various obliquity from the warmer beds incumbent over the surface of the earth. It would be most interesting to obtain the reports of both the erect and the pendant opposite æthrioscope, when carried up in the car of a balloon to the elevation of four miles. In that region of mid-air, we might expect the hot and the cold pulses, as they crossed in opposite directions, to act with nearly equal energy. The measures of those effects, compared with the simultaneous indications of the photometer, could not fail to dispel much obscurity, and to open new views of the disposition of the elements, and of the economy of nature.

Construction of the cyanometer.

VIII. Cyanometer.[2]—This instrument was contrived by M. de Saussure, to measure the variable intensity of the cærulean hue which the sky assumes in different climates and elevations, according to the progress of the day or the advance of the season. It consists of fifty-three slips of paper of about a quarter of an inch broad, stained with the successive shades of blue, from the palest sapphire to the deepest azure, which are pasted around the circumference of a circle of pasteboard of about four inches in diameter. The colours were obtained from fine Prussian blue, diluting it with white chalk, or darkening it with a mixture of ivory black. He likewise compared those coloured spaces with the pure tints of a solution of copper in ammonia, which resemble most the soft transparent hues of the atmosphere. To represent the effect of clouds, and diffuse aqueous vapours, he dropped into that liquid a portion of very fine divided argillaceous earth, precipitated by ammonia from a solution of alum.

In observing with the cyanometer, it should be held out of doors, between the eye and the part of the heavens which is to be compared, and, with a little practice, the corresponding tint is easily distinguished.

In this way, Saussure found, that the deepest blue of the zenith on the summit of Mont Blanc, at his station on the Col du Géant, at Chamouni, and at Geneva, corresponded respectively to the shades denoted 39, 37, 34, and $26\frac{1}{2}$. From morning till noon, the colour of the vertical sky darkened, but became lighter again as the evening advanced; and this transition was wider and more rapid in great elevations. On the Col du Géant, the tint of the horizontal air at sunrise was 5, it deepened to $11\frac{1}{2}$ at noon, but again relapsed to 5 towards night. On the 15th of July, which was a very clear day, the atmosphere at the horizon had the 11th shade; at the altitude of 10°, the 20th; at that of 20°, the 31st; at that of 30°, the 34th; at that of 40°, the 37th; and thence with any sensible variation to the zenith. Baron Humboldt, in his voyage from Corunna to Cumana, found the tints of the sky to vary, by the cyanometer, from 13 to 24, and again to 16, while the colour of the ocean fluctuated between 34 and 44.

The misfortune is, that we cannot annex any very distinct ideas to these numbers. We are not informed even of the proportions of the ingredients of the series of colours.

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[1] From ἀιθριος, which signifies at once *clear*, *dry*, and *cold*.

[2] From κυανος, *cærulean* or *sky-blue*, and μετρον, *a measure*.

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The manner of composition likewise will modify the colorific effect; and most of the pigments, and especially the Prussian blue, not only want uniformity of tone, but are subject to great alteration. It would be quite impossible to paint with any water colours two cyanometers that should continue to agree, after being exposed for some time to the action of the air and the sun.

Composition of colours.

If an accurate method could be devised to discriminate colours, and mark their different tints with a sort of numerical precision, it would prove a valuable acquisition to philosophy and the arts. This was first attempted by the famous painter Leonardo da Vinci. Zahn proposed, in 1702, to accomplish it, by the graduating mixture of primary colours dispersed over the surface of a triangle; but he reckoned five of those colours, including *black* and *white*, with *red*, *yellow*, and *blue*. The celebrated Professor Mayer of Göttingen, after various trials, simplified the procedure, in a posthumous work, published by Lichtenberg in 1775. Having distinguished each side of an equilateral triangle into 13 equal parts, he subdivided the whole space into 91 small triangles, which he painted with the successive mixtures of *vermilion*, *ultra-marine*, and *bright orpiment*. Lambert assumed three colours, *carmine*, *Prussian blue*, and *gamboge*, to cover a triangular base, upon which he erected a coloured pyramid, having *white* planted at its apex. But Dr Thomas Young, whose authority in those matters has deservedly great weight, prefers the simple triangle, and adopts *red*, *green*, and *violet*, for the primary colours. Their binary combinations are *yellow*, formed by mixing red with green; *crimson*, consisting of red and violet; and *blue*, produced by blending green with violet. The difficulty, however, is to regulate the intensity of the compounds; nor can the powders be safely mixed except in a dry state, lest some chemical action should be introduced which might alter their tints. But the colours thus combined must evidently want the freshness and brilliancy of those which nature paints, or which the prism reveals.

Air, like water, is, no doubt, by its constitution, a coloured fluid. The former is naturally blue, as the latter is green; but these colours acquire intensity only from the depth of the transparent mass. A small body of limpid water has the appearance of crystal, but, in proportion as it accumulates, it assumes all the successive shades, till it rivals the tints of the emerald and the beryl. This gradation is distinctly seen in the profound lakes of Switzerland, whose lustre is never stained by any vegetable infusion. The same series of colours emerges on receding from our shores and approaching the vast abyss of the Atlantic Ocean. At first, the water on the shelving banks is merely translucid; at the depth of ten fathoms it appears greenish; and the tint, by degrees, becomes more intense, till it passes into a full green at the depth of fifty fathoms; but beyond soundings it darkens almost into azure.

In like manner, the blue shade of the air becomes more intense in proportion to the length of the track of light. This we perceive in viewing distant objects, whose colours are always tinted by the deepening hues of the interjacent range of atmosphere. The remotest hills seem lost in a cærulean vesture. The mixture of aqueous vapours only diffuses a mist, which tarnishes rather than dilutes the fine blue.

It must be observed, that no substance can disclose its inherent colour, but by a sort of internal secretion or dissection of the rays of light. The mere reflexion from the surface of a solid body could never betray its tints; for, when rendered most perfect by polish, it would only, like a mirror, send back unchanged the incident beams. To detect the subjacent colour, it is necessary that the particles of light should at least penetrate under the surface, and, after suffering a sort of chemical separation, should be again emitted. In transparent substances, whether solid or fluid, the penetration is greater, but the mode of evolving the native colours must be still the same. The atmosphere, besides dispersing internally the blue rays, likewise reflects in various proportions the white light unaltered. This fact is established by some experiments of *polarization*, which show that such simple reflexions are the most copious from the portion of the sky which is 90 degrees from the sun, and regularly decline on either side to the opposite points, where they cease altogether.

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The white or compound beam of light suffering, in its passage through the air, a continual defalcation of the blue rays, must, as it advances, assume the complementary colour, or the tints of the remaining portions of the spectrum, and therefore merge successively into yellow, orange, red, and crimson. Such, accordingly, are the graduating colours of the solar rays, as they approach to their extreme obliquity. Near sun-setting, the shadow of a pencil along a blank card appears a bright azure on a lilac ground. When a diffuse attenuated vapour reflects the incident light unaltered, the western sky, as the sun declines from his altitude, glows with the successive shades of yellow and orange, which deepen finally into a blush red. These colours again may, under certain circumstances, come to be blended with the natural blue of the atmosphere. Hence the explication of a curious phenomenon, which rarely occurs in this climate, the existence of *green clouds*. This happens in the mornings and evenings, when a thin cloud is illuminated at once by the yellow rays of the sun and the bright azure of the upper sky, these contrasted colours producing a *green* by their mixture. For the same reason, sometimes a portion of the bright sky appears, in the finer climates, tinted with violet. This was remarked by Humboldt in his voyage to America, and we have had occasion to observe the same at Avignon. It was no doubt occasioned by the reddish rays of the declining sun dyeing the intense blue of the higher atmosphere.

Another form proposed.

The easiest and readiest way of ascertaining the tints of different portions of the sky is perhaps to employ a sharp wedge of blue glass, of which the base and the parallel sides are painted black and cased with thin brass, and the slanting sides are ground to true planes, and highly polished. To these angular surfaces two slides might be adapted, having each a broad slit, or intermediate opening, to permit the entrance and transmission of white light. Such rays having a greater length of passage to traverse, according to their distance from the top of the wedge, must emerge with a proportional intensity of blue. The scale would hence be determined by dividing the slides into ten or twenty equal parts, which might probably be sufficient.

To examine the orange and crimson tints which gild the east in the morning, or suffuse the western sky on the approach of evening, it would be necessary to combine a series of the complementary or accidental colours. A wedge of glass, stained of a gold-red or deep orange, might answer the purpose; or perhaps a nearer approximation would be obtained by joining two reversed wedges, one of an angle of 8°, and crimson coloured, and another having only 3°, but of a yellow body.

These instruments might be reduced to a very convenient size, not exceeding four inches in length; but they would require to be formed out of the same mass of glass and exactly after the same pattern. With some skill in the execution, they could be made to unite elegance and correctness.

Anemometer.

IX. ANEMOMETER.[1]—Various attempts have been made

[1] From *ἄνεμος*, *the wind*, and *μέτρον*, *a measure*.

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to construct an instrument that should readily indicate the force and velocity of the wind. One method was to employ a very small model of a wind-mill, and either to reckon its revolutions, or to estimate its power by the application of a weight to a conical barrel or axis. But a more direct and accurate procedure consisted in measuring the impulse of wind against a vertical plane, as intimated by the contraction of a spiral spring. All these instruments, however, act with such extreme irregularity, as scarcely ever to furnish any definite results. They are, besides, racked by incessant motion, and soon put out of order.

We may notice, however, a material improvement made in this construction of the machine by Mr Waddel of the Trinity-House, Leith, who, amidst other objects of useful experimental inquiry, has long directed his ingenuity to ascertain the force and velocity of the wind. A circular plate, of four inches diameter, is opposed to the blast; but instead of pushing against a spring, it presses against a fine cylindrical bag, of about an inch long, and the third part of an inch diameter, filled with quicksilver, and joined tight to a vertical tube of glass, a foot or fifteen inches high, but having a bore only the twentieth part of an inch wide. The compression of the bag caused by the impulse of the wind upon the plate squeezes the quicksilver up into the tube, carrying with it a small steel mark, which slightly adheres to the sides of the bore. The height of the mercurial column, diminished in the ratio of the surface of the plate to the section of the bag, must evidently give the measure of the force of the wind. But, in the actual exposure of this anemometer, the quicksilver oscillates excessively, so that the extreme effects only are indicated. The instrument, however, is very sensible, and may continue to act for a long period without being impaired.

Its improved construction.

The direct action of the wind in supporting a column of water appears to furnish the best and simplest kind of anemometer. This principle was first employed, in 1731, by Pitot, the French engineer, in his recurved tube for estimating the force of the current of a river; and, forty years afterwards, it was applied by Dr Lind to measure the impulse of a stream of air. With some modifications to correct, or at least to diminish, the oscillations of the liquid, this instrument is rendered quite manageable. The tube may consist of two pieces, each about a foot in height, having bores of the fiftieth and the fifth parts of an inch, the narrow piece being swelled out into a cylinder, perhaps an inch wide and two inches long, near the end where it is joined hermetically to the other piece. The top of the narrow tube is bent horizontally, and cemented into the centre of a vertical circle of plate-glass, of about three inches in diameter; or, instead of this plane, a hollow segment of a sphere of the same expansion, but including only 30° or 40°, is substituted. The top of the wide tube is likewise bent horizontal, and drawn to a point at the same height as the minute central orifice of the cavity, and bent in the opposite direction. A portion of nut-oil, tinged by the alkanet root, had been previously introduced into the cylindrical cistern. On turning the small plate or bason to front the wind, a condensation, corresponding to its force, is immediately produced on the opposing surface, a small portion of air enters the orifice, and continues to press upon the oil, till this rises to form an equiponderant column in the wide tube. As the air can with difficulty penetrate through the very narrow bore, the irregular action of the blast is, in a great measure, corrected, and the oil moves rather tardily.

A scale is adapted, bearing two sorts of divisions, the one indicating the impulse, and the other the velocity, of the wind. Reckoning the weight of the atmosphere equivalent to a column of oil of 400 inches in altitude, this space is subdivided into 10,000 equal portions, each degree thus corresponding to the twenty-fifth part of an inch. It would hence be easy to show, that the pressure of the wind upon every square foot of surface is expressed in pounds avoirdupois, by dividing by five the number of degrees through which the oil ascends.

But we may place an adjacent line of subdivisions, that shall mark the velocity of the wind in miles each hour. Since air will rush into a vacuum at the rate of 1350 feet in a second, it would, under a predominating pressure of the 100th part of an atmosphere, or at 100 degrees, flow with a celerity ten times less, or 135 feet in a second, which corresponds to 92 miles in an hour. Wherefore, 25 degrees of the scale of impulse would be marked by a velocity of 46 miles, and $6\frac{1}{4}$ degrees by that of 23 miles, in an hour. The subordinate divisions could hence be easily formed.

Such are the velocities which theory would assign to the different altitudes of the columns supported by the force of the wind. But the actual resistance of fluids, owing chiefly to their detention at the obstructing surface, generally exceeds the result of calculation. In the case of water and air, the ratio of excess appears from experiment to be nearly that of eight to five. We may therefore modify the velocities after this proportion above stated. The relations of celerity and impulse will stand thus:

Celerity in Miles per Hour.	Impulse in 10,000th Parts of the Weight of the Atmosphere.
10	1°·9
20	7 ·6
30	17 ·1
40	30 ·4
50	47 ·5
60	68 ·4
70	93
80	121 ·5

This anemometer, being furnished with a vane to make it always face the wind, might also, by an index, point out the direction. Nor is it absolutely requisite that the instrument should be exposed out of doors. The funnel, with its vane, may have a socket of bell-metal, nicely fitted to the top of a long perforated brass tube, which descends from the roof of the house, and terminates below in the recurved tube and its double scale. The impressions of the wind would thus be conveyed with great regularity and undiminished effect to the surface of the oil. Still, however, it would be impossible to avoid entirely the oscillations of the liquid column. Even the steadiest wind will be found to blow with a reciprocating force, now swelling and again relaxing, and, at certain short intervals, concentrating all its vehemence.

Ombrometer.

X. Ombrometer,[1] or Rain-Gauge.—A very simple instrument, contrived to indicate the quantity, or rather the depth, of the rain which falls upon any spot. It is likewise named *Hyetometer*, and has been sometimes called by the barbarous compound *Pluviameter*. It is composed generally of a circular bason of tinned iron, soldered to the top of a vertical cylinder, which is contracted in some given proportion, and closed below. A small float is introduced, bearing a slender rod, distinguished by the corresponding divisions. In the most ordinary construction,

[1] From ὄμβρος, *rain*, and μετρον, *a measure*.

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the bason being a foot wide, the attached cylinder has $3\frac{4}{5}$ inches in diameter, and its section is consequently ten times smaller. The inches on the rod are hence marked only tenth parts.

This method of measuring the fall of rain is evidently not susceptible of much accuracy; and it would require the gauge to be very frequently visited, on account of the loss of the water by continual evaporation. The more correct ombrometers have their bason made of brass, and turned to a fine sharp edge; the rain, as it falls, runs through a small orifice into the vertical cylinder, which has only about the fourth part of the diameter, and communicates, by means of a cock, with another perpendicular tube still narrower, and consisting of glass having a scale affixed. The divisions of this scale are determined from the proportion of the joint sections of the cylinder and tube to the horizontal surface of the bason. In making an observation, the cock, being turned, lets the collected water rise to the same level in the glass tube, and thus indicate its quantity, which, by another operation, is now drawn off. In the time of frost or snow, it becomes necessary to warm the instrument gently, and make the water flow.

We may suspect that the measure of the rain, hail, or snowy flakes received by the ombrometer, is not exactly proportioned to the extent of surface which it presents; for, while torrents pour down from the heavens, an eddy plays about the rim of the bason, deranging the regularity of the discharge. A bason of several feet in diameter would perhaps be preferable, or the platform of a roof could be adopted, if it were sufficiently sloped to allow the rain to collect quickly.

Its variable indications.

But the most perplexing circumstance affecting the ombrometer is, that it has been found to indicate very different quantities of rain as falling upon the very same spot, according to the different elevation at which it was placed. In general, less rain is collected in high than in low situations, even though the difference of altitude should be inconsiderable. Thus it was discovered, that, in the space of a year, while 12·1 inches only fell on the top of Westminster Abbey, 18·1 inches were collected on the roof of a house sixteen feet lower, and even 22·6 inches of rain at the ground. Similar observations have been made at the summit and near the base of hills of no great elevation. In such situations, we can hardly suppose the clouds to stretch down to the surface, or to augment the lower portion of rain. We must hence refer the copious fall near the ground to some other cause. Most of the rain which falls proceeds from drifting showers of short duration. The current moves more slowly along the surface, and allows the drops to descend as fast as they are formed. But being forced to mount a swelling eminence, and thus compressed into a narrower stream, it hurries the mass of vapour along with it, and does not suffer the free or full discharge on the summit. On both sides of the hill, an ombrometer placed near the bottom indicates always a greater fall of rain than on the exposed top.

The observations furnished by this instrument are hence liable to considerable inaccuracy, unless made in an open champaign country. Thus, a register kept at Keswick gives $67\frac{1}{2}$ inches, which evidently exceeds greatly the annual fall of rain in that district; the quantity at Carlisle, not twenty-five miles distant, being only 20 inches. Again, the measures of rain, being 33 and $34\frac{1}{2}$ inches in the open country about Manchester and Liverpool, are found to amount to 45 and 60 inches at Lancaster and Kendal, which approach the flanks of a mountainous range. In general, twice as much rain falls on the western as on the eastern side of our island; and the average annual quantity may be reckoned at 30 inches, or it would form, if all collected, a sheet of water of that depth. According to this estimate, the whole discharge from the clouds in the course of a year, on every square mile of the surface of Great Britain, would, at a medium, be 1,944,643, or nearly two millions of tons. This gives about three thousand tons of water for each English acre.

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XI. Electrometer,[1] which detects the electrical state of the lower atmosphere. The best instrument of this kind undoubtedly is Bennet's, consisting of two slips of thick gold leaf suspended from a knob within a small cylinder of glass, which is surmounted by a cap of brass. This may be connected with an insulated rod or wire, extending a few feet beyond the window. Electrometer.

The electrometer indicates the condition of the air only in its immediate vicinity. But when thunder-storms prevail, the atmosphere becomes affected to a very considerable extent. Yet the indications of the electrometer are often capricious and evanescent. Whenever clouds are suddenly formed, or melt away, whether the air changes to dryness or humidity, the electrical equilibrium is disturbed. The observations made with the electrometer are hence of much less importance than was once expected, and have been gradually falling into neglect.

XII. Drosometer.[2]—An instrument so called was proposed by Weidler, a German professor, in 1727, to measure the quantity of dew which gathers on the surface of a body which has been exposed to the open air during the night. It consisted of a bent balance, which marked in grains the preponderance which a piece of glass of certain dimensions, laid horizontally in one of the scales, had acquired from the settling and adhesion of the globules of moisture. Drosometer.

The main objection to a drosometer of such a construction is, that it would require to be protected from the action of the wind; and being thus screened, it could not receive the whole of the dew which might otherwise have been deposited. The steel beam, too, from continual exposure to the weather, would soon lose its polish, and become unfit for any accurate performance. Besides, it is in general easier to measure than to weigh a portion of liquid.

A simpler and more convenient drosometer could be formed on the principle of the ombrometer, or rain-gauge. Suppose a glass funnel, of about three inches diameter, whose interior surface is very smooth, and slopes towards the centre at an angle of 15 or 20 degrees, to be joined hermetically to a long tube, sealed at the lower end, and having an equable bore not exceeding the quarter of an inch, with an attached scale divided into portions corresponding to the thousandth parts of an inch on the external aperture. The only difficulty is to make the dew which gathers during the night to run down the sides of the funnel into the tube. To facilitate this descent, a coat of deliqueate salt of tartar may be spread with a hair pencil over the shallow surface, and renewed as often as occasion requires. The dew, instead of settling in minute detached globules, would then be attracted by the alkaline lye, which thus, becoming dilute, would gradually flow into the narrow cavity of the tube. It would be easy at any time to make an allowance for the very small portion of liquid alkali blended with the dew.

Such is the complete apparatus required for keeping a meteorological register. But those instruments are not all of equal importance. The barometer, the thermometer, and the hygrometer, may be considered as indispensable. Next to them deserve to be ranked the photome-

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[1] From ἤλεκτρον, *amber*, and μέτρον, *a measure*.

[2] From δρόσος, *dew*, and μέτρον, *a measure*.

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Meteorological registers.

ter and æthrioscope, which disclose the more recondite condition of the atmosphere. The atmometer, the ombrometer, and the anemometer, besides, are of consequence, from the practical results which they furnish.

The value of any meteorological register, however, depends on the accuracy with which it is kept. The observations should be made in a place rather elevated, and exposed freely on all sides to the aspect of the sky; and they should be repeated either at equal intervals, during day and night, or at least at those hours which represent most nearly the mean state of the atmosphere. These requisites are seldom attained, and very few registers of the weather, accordingly, are entitled to much confidence.

It cannot be expected that registers of the weather will possess much value, so long as they are kept merely as objects of curiosity. Like astronomical observations, as now conducted, they should no longer be left to the chance of individual pursuit. They would require to be unremittingly prosecuted in all variety of situations, and at the public expense. Proper sets of meteorological instruments should be placed, not only in the regular observatories, but sent to the different forts and light-houses, both at home and at our principal foreign stations. They might also be distributed among the ships employed in discovery, or engaged on distant voyages. The cost of providing those instruments would be comparatively trifling, and the charge incurred by keeping registers on a regular and digested plan might shrink to nothing in the scale of national expenditure.

The state of the barometer alone is kept with tolerable accuracy, because that instrument, being little influenced by collateral circumstances, marks nearly the same impressions over a wide extent of surface. The thermometer, again, is seldom observed at the proper hours, or in a situation sufficiently detached from the buildings and solid walls.

It is customary, for the sake of convenience, to note the thermometer in the morning, at the height of the day, and again in the evening. But these three observations must evidently furnish results below the medium temperature of the whole twenty-four hours, since the accumulated warmth is reckoned but once, while the freshness partaking of the night is counted twice. It would be nearer the truth to assume the middle point between the maximum and minimum, though even this cannot be deemed absolutely correct, because the heat neither mounts nor declines in an uniform progression. The hottest time of the day is generally about two o'clock, and the coldest just before sunrise. This hour of extreme descent is consequently very variable; and it would be difficult to fix the times suited for observing, unless they were more multiplied. But even fewer observations may sometimes be made to serve the purpose. In this climate, the daily average may be reckoned from eight o'clock in the morning, and the month of October is found to have nearly the mean temperature of the whole year.

The observations usually made with the hygroscopes of Deluc or Saussure cannot be regarded as affording any definite indication of the dryness of the atmosphere. It would essentially contribute to the advancement of meteorological science, if the hygrometer which we have described were introduced into general practice. This adoption cannot be very distant.

Some of the monks, in the religious houses scattered over the Continent, might find an agreeable and useful occupation in recording the state of the atmosphere. Many of these establishments are scattered in lofty and romantic situations; and several of them, destined by their founders for the charitable accommodation of travellers, occupy the summits of the most elevated and inaccessible mountains. Accurate registers kept in such towering spots are peculiarly interesting.

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Light-houses would, from their usual position, be well fitted for observing the force and direction of the wind, and the swell and relapse of the tide. The navigators who traverse the ocean in every latitude might, besides keeping meteorological soundings, record the variation of the needle, and examine the intensity of magnetic attraction.

To promote the science of meteorology, it would be most expedient that the various learned associations planted in different parts of the globe, should institute inquiries into the state and internal motions of the higher strata of our atmosphere. As the ultimate results could not fail to prove advantageous to the public, the several governments might be expected to defray the moderate expense incurred in carrying this plan into effect. Light small balloons might from time to time be launched towards the most elevated regions, to detect by their flight the existence and direction of currents which now escape observation. Barometers, thermometers, hygrometers, and perhaps æthrioscopes, in compact forms, and which should register themselves, might be sent up in the car. Observers, furnished with accurate and complete instruments, could likewise be despatched occasionally to the intermediate heights in large balloons. By classing the various meteorological journals, and combining those ulterior facts, some new lights could not fail to be struck out, which would gradually reveal that simple harmony which no doubt pervades all the apparent complication of the universal frame. Till we obtain such insight, we must content ourselves with the best explications of the phenomena of the atmosphere, which our imperfect and limited knowledge will admit. We shall, therefore, treat in succession of the origin of winds; the generation of clouds and fogs; and their precipitation in the form of rain, snow, or hail. Other collateral objects will be discussed as they present themselves to view.

I. Wind.—It is a curious circumstance, that in all languages the ordinary name of *air* refers to its mobility, and merely signifies *to blow*. This impulse alone of the fluid appears to have awakened our sensations; and had the atmosphere continued perfectly still, we might for ages have remained ignorant of the very existence of the fluid which we breathe.

Cause of wind.

The main cause of *wind*, or the flow of air, is undoubtedly the variable distribution of heat through the atmosphere, which incessantly affects the local density, and disturbs the equilibrium of the mass. The presence of the sun affects the surface of the terraqueous globe, which again warms and dilates the lower strata of atmosphere. The calorific action of the solar beams is greatly diminished by their obliquity; it rapidly accumulates on the land, but becomes attenuated and diffused in the waters of the ocean.

The alternation of day and night, and the annual revolution of the seasons, are hence the perpetual sources of winds. If the surface of the globe, however, had been wholly covered by the ocean, and not disparted by land and seas, those winds must have been scarcely perceptible. The daily illumination of the sun does not warm the ground to the depth of an inch; but the same quantity of illumination penetrates, though with a decreasing intensity, many fathoms into water, spreading and dividing its influence. We may reckon the tenth part of the incident light to be intercepted by a superficial stratum of the thickness of one foot; and it will hence follow, that the solar beams communicate every day a hundred times less heat to the surface of a body of water than to an expansion of level ground. The subsequent influence, again, of those contrasted surfaces in warming the incumbent air must be proportionally different, though slightly modified

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by the portion of light reflected from the water. In a general view, the diurnal variation of temperature in the atmosphere may be considered as limited to the lowest stratum, not exceeding 2000 feet in height. Such a body of air will intercept commonly the fiftieth part of all the light which traverses it. We may hence conclude, that the change of temperature in the air, caused by the succession of day and night, is, on the whole, about thirty times less above a spacious lake than over the surrounding land.

The current which rushes from all sides towards any heated portion of the atmosphere is easily explained and computed from the diminution of pressure which rarefaction produces at that place. The celerity of the flow is precisely the same as that of the efflux from a small aperture under the pressure of a column equivalent to that diminution, or to the difference between the weight of the warm air and of an equal volume of the exterior fluid. Thus, suppose a chimney 20 feet high were heated up 50 centesimal degrees, or 90 on Fahrenheit's scale; the air in the flue being therefore expanded one fifth part, or four feet, would be driven upwards by the pressure of a column compensating this difference. The velocity of the discharge would hence be $8\sqrt{4} = 16$ feet every second, or at the rate of about eleven miles in the hour. If a fire be kindled in an open field, it is evident that the rush of air must proceed from all sides. At the spot itself, therefore, the opposite currents will produce a counterbalance, and no dominant wind can prevail. But if the warm air should cover a very wide extent of surface, its influence may be felt at a great distance, and the several converging winds may have space to blow without any mutual interference.

Sea and land breezes.

These views afford a complete explication of the phenomena of sea and land breezes, which are occasionally met with in every latitude, but are constantly observed near the shores of the continent, and of the larger islands within the tropics. In those sultry regions, as the day advances, a refreshing wind blows from the sea, and is succeeded by an opposite current from the interior of the land on the approach of evening, and during a great part of the night. In open seas, and especially near the equator, the thermometer scarcely varies a degree, and very seldom two degrees, by Fahrenheit's scale, in the whole course of a day. But on the land, the change of temperature between the night and day, in similar situations, will rise often higher than 76 centesimal degrees, or 126 of Fahrenheit. If we, therefore, conceive a stratum of air 2000 feet in altitude, heated only to the mean difference, or three centesimal degrees, it would receive an expansion of 24 feet; whence the velocity of the wind produced would be $8\sqrt{24} = 39$ feet every second, or at the rate of 26 miles in the hour. This is a very moderate estimate; but the celerity of the current must, no doubt, be diminished, from the retardation which it suffers in proportion to the length of track over which it has to sweep.

During the night the lower atmosphere is colder on land than at sea, owing partly to the descent of the more elevated and colder portions of air which chill the surface of the ground, and partly to those cold pulses which are incessantly darted from every point of the azure sky. If we reckon the reduced temperature of the land only a centesimal degree and a half below the standard of the adjacent ocean, this would give 12 feet for the contraction of the vertical column of air, and, consequently, a stream would flow towards the sea with a celerity of $8\sqrt{12} = 28$ feet per second, or very nearly 20 miles every hour. In general, the land breeze may be considered not so powerful as what blows from the sea.

The ordinary appearances are clearly and graphically described by that very intelligent and enterprising navigator Captain Dampier.

"These sea-breezes do commonly rise in the morning about nine o'clock, sometimes sooner, sometimes later. They first approach the shore so gently, as if they were afraid to come near it; and ofttimes they make some faint breathings, and, as if not willing to offend, they make a halt, and seem ready to retire. I have waited many a time, both ashore to receive the pleasure, and at sea to take the benefit of it.

"It comes in a fine, small, black curl upon the water, when as all the sea between it and the shore not yet reached by it is as smooth and even as glass in comparison. In half an hour's time after it has reached the shore it fans pretty briskly, and so increaseth gradually till twelve o'clock; then it is commonly strongest, and lasts so till two or three a very brisk gale. About twelve at noon it also veers off to sea two or three points, or more, in very fair weather. After three o'clock it begins to die away again, and gradually withdraws its force till all is spent, and about five o'clock, sooner or later, according as the weather is, it is lulled asleep, and comes no more till the next morning.

"These winds are as constantly expected as the day in their proper latitudes, and seldom fail but in the wet season. On all coasts of the main, whether in the East or West Indies, or Guinea, they rise in the morning, and withdraw towards the evening; yet capes and headlands have the greatest benefit of them, where they are highest, rise earlier, and blow later.

"Land-breezes are as remarkable as any winds that I have yet treated of: they are quite contrary to the sea-breezes; for those blow right from the shore, but the sea-breeze right in upon the shore; and as the sea-breezes do blow in the day and rest in the night, so, on the contrary, these do blow in the night and rest in the day, and so they do alternately succeed each other. For when the sea-breezes have performed their offices of the day, by breathing on their respective coasts, they in the evening do either withdraw from the coast, or lie down to rest. Then the land-winds, whose office is to breathe in the night, moved by the same order of divine impulse, do rouse out of their private recesses, and gently fan the air till the next morning; and then their task ends, and they leave the stage.

"There can be no proper time set when they do begin in the evening, or when they retire in the morning, for they do not keep to an hour; but they commonly spring up between six and twelve in the evening, and last till six, eight, or ten in the morning. They both come and go away again earlier or later, according to the weather, the season of the year, or some accidental cause from the land; for on some coasts they do rise earlier, blow fresher, and remain later, than on other coasts, as I shall show hereafter.

"These winds blow off to sea, a greater or less distance, according as the coast lies more or less exposed to the sea-winds; for in some places we find them brisk three or four leagues off shore, in other places not so many miles, and in some places they scarce peep without the rocks, or, if they do sometimes in very fair weather make a sally out a mile or two, they are not lasting, but suddenly vanish away, though yet there are every night as fresh land-winds ashore at those places as in any other part of the world.

"Indeed, these winds are an extraordinary blessing to those that use the sea in any part of the world within the tropics; for as the constant trade-winds do blow, there could be no sailing in these seas; but, by the help of the sea and land breezes, ships will sail 200 or 300 leagues, as particularly from Jamaica to the Lagune of Trist, in the Bay of Campeachy, and then back again, all against the trade-wind.

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"The seamen that sail in sloops or other small vessels in the West Indies do know very well when they shall meet a brisk land-wind, by the fogs that hang over the land before night; for it is a certain sign of a good land-wind to see a thick fog lie still and quiet, like smoke over the land, not stirring any way; and we look out for such signs when we are plying to windward. For if we see no fog over the land, the land-wind will be but faint and short that night. These signs are to be observed chiefly in fair weather; for in the wet season fogs do hang over the land all the day, and it may be neither land-wind nor sea-breeze stirring. If in the afternoon, also, in fair weather, we see a tornado over the land, it commonly sends us forth a fresh land-wind.

"These land-winds are very cold, and though the sea-breezes are always much stronger, yet these are colder by far. The sea-breezes, indeed, are very comfortable and refreshing; for the hottest time in all the day is about nine, ten, or eleven o'clock in the morning, in the interval between both breezes; for then it is commonly calm, and then people pant for breath, especially if it is late before the sea-breeze comes, but afterwards the breeze allays the heat. However, in the evening again, after the sea-breeze is spent, it is very hot till the land-wind springs up, which is sometimes not till twelve o'clock or after." (*Voyages*, vol. ii.)

Nature of the trade-winds.

The TRADE-WINDS, which, within the tropics, at all times constantly blow from the east, but somewhat vary their force, and decline a little to the north or the south, according to the latitude and the season, are the most remarkable of all the aërial currents, and of signal importance in navigation. These steady breezes favoured the voyage of Columbus, and conducted him to the discovery of the Mexican archipelago. The same powerful stream afterwards drew the Portuguese from their southern course, and carried them to the shores of the Brazils. Since the character and extent of those winds have become perfectly known, the navigator reckons safely on their aid, and shapes his voyage in such a way as to reduce its performance almost to a calculation.

The cause of the trade-winds, however, is not obvious, or very easily traced. Various attempts have been made to explain the phenomenon, yet seldom on any solid or accurate principles. It would form an interesting discussion to examine the different hypotheses advanced; but we can afford room to notice, very briefly, the more considerable only of those opinions.

Descartes and his followers imputed the trade-winds to the inertia of the atmosphere, which they conceived to prevent this fluid from acquiring the full rotation of the earth, especially near the equator. The air being thus left behind as the globe rolled from the west, would have an apparent motion in the contrary direction, and seem to blow from the east. But it may be urged, that as passengers almost insensibly gain the celerity of the ship which carries them, so every portion of the incumbent atmosphere, though more loosely adherent to the terraqueous surface, must soon acquire the peculiar motion corresponding to the parallel of latitude. Nor would the inequality of such combined movements in the air at all disturb the order and arrangement of its general mass.

Halley's hypothesis.

Dr Halley gave a different explication of the origin of trade-winds, which seems very plausible, and has long been deemed quite satisfactory. This able philosopher and experienced navigator supposed, that the spot where the sun's vertical rays exert their utmost heating energy, being in the lapse of a day successively transferred from east to west round the circumference of the globe, must, as a centre of confluence, draw in its train a current of air. The current thus formed would result from the excess of the streaming from the east above that from the west; and it would therefore advance with a tardy pace, following at a distance the powerful energy of the sun. The same easterly wind might incline towards the north or the south, according as the great luminary appears to approach to the northern or the southern tropic.

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But it should be observed, that the torrid zone stretches mostly over the ocean, and includes only a narrow portion of land. The heat excited in succession through that liquid track, by the diurnal passage of the sun, is hence extremely small, and hardly sufficient to produce the aspiration of the gentlest air. Nor could even this feeble current have a decided and constant direction. It would only tend towards the heated part of the surface of the ocean. In the morning, it would breathe from the west; about noon, it would become neutral, and die away; and, in the evening, it would again spring up, and flow from the east. Near midnight this current would sink into a perfect calm. The hypothesis will, therefore, not bear any strict examination. It is neither adequate to the production of such effects, nor accordant with the actual phenomena of the trade-winds. It casts a false glare over the subject, without elucidating its real bearings.

True theory.

The first who succeeded in taking a correct view of the question was George Hadley, in a short paper inserted in the Philosophical Transactions for 1735. By combining in some measure the idea of Descartes with the opinion of Halley, he produced a clear and simple account of the cause of trade-winds, which appears entirely consistent, and free from every objection. Though the daily variation of temperature be very inconsiderable within the tropics, yet the annual accumulation of heat renders the equatorial regions much warmer than the higher latitudes, and consequently maintains a perpetual current of air from either side. If those aërial motions were not modified by the figure and rotation of the globe, there would always be two opposite winds blowing directly from the north and from the south to the equator. But the stream which perhaps originates at the northern tropic, in advancing to the equator, must seem gradually to deflect towards the west, in consequence of the increasing velocity with which the successive parallels of latitude are carried eastwards. During the time this current takes to perform its journey, it is apparently transported to the west, through a space equal to the excess of the arc described by the equator above the corresponding arc traced by the tropic. The current from the southern tropic is equally bent towards the west. When both of them meet at the equator, their opposite impulsions from the north and the south are extinguished, and they flow directly west in a single united stream, and with accumulated force. The apparent motions of the different streamlets which from both hemispheres conspire to constitute the trade-wind, is represented in fig. 18, Plate CCCLV.

Its details.

But it is not enough to connect the general facts; a complete theory should harmonize in all the subordinate details. An easy calculation, accordingly, is conducted to those precise results which are commensurate and exactly congruous with the actual phenomena. The trade-wind may be reckoned to begin about the latitude of 25 degrees. At this parallel, the mean temperature is four centesimal degrees colder than immediately under the equator, which difference of heat may graduate through the atmosphere to the altitude of 10,000 feet. Wherefore, the expansion of the air at the equator, which draws to it a meridional wind, will amount to a column of 100 feet. The velocity of the current hence produced must be $8\sqrt{100}$, or 80 feet every second, which corresponds to fifty-four miles in the hour. But each point on the parallel of 24° is carried eastwards by its revolution about the earth's axis seven miles faster every hour than on the parallel of 25°. Consequently, when the wind arrives at the parallel of 24°, it

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will seem to have acquired a tendency of seven miles an hour to the west. As it reaches the successive parallels of 23°, 22°, 21°, &c. it will gain continual, though decreasing, additions to its apparent westerly course, which at the equator will have augmented to 104 miles in the hour.

In this calculation we have made no deduction for the resistance which the streams of air must experience in sweeping over the surface of the globe, because no experiments have been made to ascertain the effect of such retardation. It is no doubt less on the ocean than on the land, and must evidently be diminished in proportion to the depth of the mass of fluid which is borne along. Still, however, this obstruction, joined to this impediment of internal motion, must be very considerable; and we may safely reduce the numbers before stated to one third, which would give eighteen miles an hour for the celerity of the primary meridional wind, and thirty-five miles for that of the oriental or trade-wind, resulting from the influence of the figure and rotation of the earth.

Our northern hemisphere, presenting to the action of the solar beams a larger surface of land than the southern, is, on the whole, rather warmer. Hence the parallel of greatest heat runs not exactly through the equator, but about three degrees farther north. This circle is therefore strictly the mean path of the aggregate easterly streams of air.

But though the hottest part within the torrid zone, taking the average of a whole year, occupies the parallel of three degrees north latitude, it must, to a certain extent, shift its position with the seasons. In the summer months the sun shines twice vertical upon the tropic of Cancer, and consequently raises the temperature of the northern half of the zone. During winter, again, this effect is transferred to the southern half of the torrid region. In the progress of summer, therefore, the trade-wind gradually bends about a point towards the north; but as winter advances, it declines as much to the south.

Such is the character of that general wind which encircles the globe, flowing with slight deviation constantly from the east, and spreading over a zone of more than 50° in breadth. It sweeps the Atlantic Ocean from the coast of Africa to Brazil, and the Pacific from Panama to the Philippine Isles and New Holland, and again the Indian Seas partially from Sumatra to Zanguebar.

Monsoons.

The trade-wind undergoes an essential modification, however, where the continent stretches into the torrid zone. The sun acting more powerfully upon the land than upon the surface of the sea, the accumulated warmth is much greater, and shifts with the revolution of the seasons on either side of the equator. The centre of heat approaches in summer to the northern, and in winter to the southern tropic. Instead of the great eastern stream, those regions have two opposite periodic winds alternating towards the north and the south, and called the *monsoons*. When these winds advance to the equator, they conjoin an apparent easterly velocity; but when they recede from the equator, they carry their excess of velocity from the west. A diagonal motion results from the combined tendencies. In the Arabian and Indian Seas, on the north side of the equator, the monsoon blows north-west during the summer months, from April to October; and in the opposite direction, or south-east, during the winter. But on the south side of the equator, near Java and Sumatra, the course of the monsoon is north-east in summer and south-west in winter.

The primary winds, which blow from the parallels of 25° or 30° to the equator, must evidently give rise to opposite currents that flow in the higher atmosphere towards the poles. These streams, after they have travelled beyond the tropics, may descend to the surface, transporting the celerity of equatorial rotation. They will appear, therefore, to blow from the western quarter, with the excess of their previous velocity above that of the parallel which they reach. Hence a westerly breeze, of considerable force and regularity, prevails in either hemisphere above the latitude of 30°. The same winds cross the Atlantic from Newfoundland to Cornwall, and traverse the Southern Ocean from the Plata to the Cape of Good Hope, and thence to New Holland. Any wind which blows from the quarter inclining to the south of the west comes really from the equatorial region, and is therefore relatively warm. Such is the disposition of our westerly winds, which commonly prevail for nine months in the year.

On the same principle, a wind which blows directly from the arctic pole, and impregnated with intense cold, must, in consequence of the rotation of the globe, appear to arrive from some point to the north of the east. In passing through the first degree of latitude, it will suffer a deflection of eighteen miles in the hour towards the west; in a short space, therefore, it will seem to flow with impetuous force, and almost directly from the east. Hence our easterly and north-easterly winds have a polar origin, and are always bitterly cold.

Local winds.

Local winds could be explained if the different circumstances which affect them were distinctly known. The latitude and temperature of the place, its relative position, the figure and contour of the surrounding country, would all enter into the calculation. We shall content ourselves with a concise notice of some peculiar winds. The *Bize* is a cold piercing wind which blows from the ridge of the Jura, and the frozen summits of the Pyrenees. The *Sirocco* is a hot, moist, and relaxing wind, which visits Naples and the south of Italy from the opposite shores of the Mediterranean. The *Harmattan* seems to be a cold and dry wind, of a very parching quality, which is frequent in Africa and some of the eastern countries. The *Samiel*, or *Simoom*, is a burning pestilential blast, extremely arid, which springs up at times in the vast deserts of Arabia, and rushes with tremendous fury, involving whole pillars of sand.

Theory of clouds.

II. Clouds and Rain.—Their formation and dissolution produce all the varied train of the meteorological phenomena. The humidity suspended in the atmosphere is derived by exhalation partly from the land, but ultimately from the vast expanse of the ocean. A surface of lake, of pasture, corn fields or forest, supports a continual evaporation, augmented only by the dryness of the air, and the rapidity of its successive contacts. Even ploughed land will supply nearly as much moisture to the exhaling fluid as an equal sheet of water. It is only when the ground has become quite parched that it obstinately retains its latent store.

If the whole of the waters which fall from the heavens were to return again, the evaporation from the ground might be sufficient alone to maintain the perpetual circulation. But more than one third of all the rains and melted snows are carried by the rivers into the ocean, which must hence restore this continued waste. The commerce of land and sea is thus a necessary part of the economy of nature.

The air, in exhaling its watery store, is rendered quite damp; but it may afterwards become dry on being transported to a warmer situation. Such is the case of the sea-breeze, particularly in summer. It arrives on the shore cold and moist; but as it advances into the interior of the continent it grows milder and drier. The same principle accounts for the disposition of different winds in respect to humidity. At Colombo, in the island of Ceylon, as we gather from some remarks of Dr Davy, the north-east monsoon, with a temperature of only 68 on Fahrenheit's scale, has yet a dryness of 75 hygrometric degrees; but the opposite monsoon, from the south-west, though at 82 by the

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thermometer, is so damp as to indicate scarcely 30 degrees. The cold wind, coming from the north, was rendered warmer and drier in its progress; while the hot wind, flowing from the equator, was somewhat chilled and made damper as it approached Ceylon.

Since air in mounting upwards has its capacity for heat enlarged, and becomes colder, it will hence likewise grow proportionally damper. But a continual intercourse being maintained between the lower and the higher atmosphere, the middle region must, from its chillness, be soon charged with moisture. If this tendency were to act, therefore, without control, the heavens would have been shrouded with perpetual clouds and darkness, and never could the cheering rays of the sun have visited the surface of the earth. A principle of conservation happily occurs to restrain, and finally to overpower, the effect of cold, in disposing air to part with its moisture. By expansion, this fluid is made capable of holding, at the same temperature, a larger share of humidity. Each portion of air, in rising vertically, grows, from the predominance of cold, constantly damper; but after having reached a certain altitude, it again becomes gradually drier, from the influence of its wide dilatation. Every time the air has its volume doubled, it acquires an additional dryness corresponding to fifty hygrometric degrees. Hence one degree would be the effect of the rarefaction of only the 72d part. This small variation again answers to a depressed temperature of $1\frac{4}{9}$ on the centesimal scale, which, near the surface, will occasion an increase of humidity equal to the actual range of the solvent power of the air divided by 31·4. Suppose the thermometer to mark 15° centesimal at the ground, the air would, for each ascent of about 390 feet, be $\frac{200}{31{\cdot}4}$, or 8 hygrometric degrees damper, which would be reduced to 7° by the influence of dilatation. Had the temperature at the surface been as low as — 25°, which answers to a solvent power of $31\frac{1}{2}$°, the opposite agencies of cold and rarefaction would evidently have produced a perfect balance, and the same dryness would have continued to a moderate height.

Their mean height.

It would be easy to show that d, expressing the density of the air at any altitude, and h the corresponding indication of the hygrometer, $\frac{h}{62{\cdot}8}\left(\frac{1}{d}+d\right)$ will denote the increment of humidity occasioned by depressed temperature, while the corresponding decrement resulting from expansion is one degree. Hence at the pole the position of the *maximum* humidity in the atmosphere must occur at an elevation of 13,300 feet; where the density is ·6, the temperature would stand at 26·7°, and the hygrometric range only 29°. Under the equator, that limit would attain a much greater altitude, and yet not rise so far above the curve of perpetual congelation. It is probable, however, that the canopy of clouds descends considerably lower, being warmed by the hot pulses darted from the ground and the inferior strata of the atmosphere. We shall not err much if we estimate the position of extreme humidity at the height of two miles at the pole, and four miles and a half under the equator, or a mile and a half beyond the limit of congelation. This range is represented in fig. 18, Plate CCCLV. running nearly parallel to the curve of perpetual congelation, but bending nearer in approaching the equatorial parts. It marks the mean height of the clouds in different latitudes, and intimates the shading into the fine etherial expanse.

Modification of clouds.

The moisture deposited by a body of air in minute globules, which remain suspended, or subside slowly in the atmosphere, constitutes a *Cloud*. When it comes near us, whether it hovers on the tops of the hills, or spreads over the valleys, it receives the name of a *Fog*. The cold occasioned by the ascent or transfer of air may be sufficient to form thin clouds, but a more powerful and extended energy is required for the production of *Rain*. The subject has from the earliest times engaged the attention of philosophers, who have made numerous unavailing attempts to explain it. At length the very ingenious Dr James Hutton subjected the problem to a correct analysis, and succeeded in deducing a most satisfactory solution. His fine Theory of Rain, which first appeared in the Transactions of the Royal Society of Edinburgh for the year 1787, constitutes an epoch in meteorological science. Its merits, however, have been slowly perceived by the public, because the author, full of his original conception, satisfied himself with merely sketching the general outline. But it was not enough that the operation of the principle advanced should always cause rain; it was farther requisite that the results arising from its application should quite accord with the actual phenomena. We shall, therefore, endeavour to render this theory more definite and more complete.

Hutton's theory of rain.

Air in cooling becomes ready, we have seen, to part with its moisture. But how is it cooled in the free atmosphere, unless by the contact or commixture of a colder portion of the same fluid? Now, the portion of the air which is chilled must in an equal degree warm the other. If, in consequence of this mutual change of condition, the former be disposed to resign its moisture, the latter is more inclined to retain it; and, consequently, if such opposite effects were balanced, there could, on the whole, be no precipitation of humidity whatever. The separation of moisture, on the mixing of two masses of damp air at different temperatures, would therefore prove, that the dissolving power of air suffers more diminution from losing part of the combined heat, than it acquires augmentation from gaining an equal measure of it; and, consequently, this power must, under equal accessions of heat, increase more slowly at first than it does afterwards, thus advancing always with accumulated celerity.

Illustrations.

The quantity of moisture which air can hold thus increases in a much faster ratio than its temperature. This great principle in the economy of nature was traced by Dr Hutton from indirect experience. It is the simplest of the accelerating kind, and perfectly agrees with the law of solution which the hygrometer has established. Suppose equal bulks of air in a state of saturation, and at the different temperatures of 15 and 45 centesimal degrees, were intermixed, the compound arising from such union will evidently have the mean temperature of 30°. But since at these temperatures the one portion held 200 parts of humidity, and the other 800, the aggregate must contain 1000 parts, or either half of it 500; at the mean or resulting temperature, however, this portion could only suspend 400 parts of humidity, and, consequently, the difference, or 100 parts, amounting to the two hundredth part of the whole weight of air, must be precipitated from the compound mass.

As another illustration, let air of 15° be mixed with air at the temperature of 35°, in three different proportions, all at the point of saturation; one part being combined with three parts, two with two, and three with one. The temperatures arising from the commixture would be 20°, 25°, and 30°; the corresponding parts of moisture precipitated from the mass being derived from the intermediate proportions of 200 and 504, are, 352, 317·5 or 34·5; 276, 252 or 24; 352, 317·5 or 34·5; and 428, 400 or 28. These depositions are represented in fig. 8, Plate CCCLV. by the several intervals between the logarithmic curve and the oblique line which connects the summits of the ordinates of 15° and 35°.

In these examples we have assumed the portions of differently heated air to be quite charged with moisture be-

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fore mixing; but it is only required that they should approach to the point of humidity. The effect, however, of simple commixture would, in most cases, be very small. To explain the actual phenomena, we must have recourse to the mutual operation of a chill and of a warm current, driving swiftly in opposite directions, and continually mixing and changing their conterminous surfaces. By this rapidity, a larger volume of the fluid is brought into contact in a given time. Suppose, for instance, the one current to have a temperature of 50, and the other that of 70 degrees, by Fahrenheit's scale; the blending surfaces will, therefore, assume the mean temperature of 60°. Consequently, the two streams throw together 200 and 334·2 parts of moisture, making 567·1 parts for the compound, which, at its actual temperature, can hold only 258·6 parts: the difference, or 8·6 parts, forms the measure of precipitation, corresponding to the 2325th of the whole weight of the commixed air. It would thus require a column of air 30 miles in length to furnish, over a given spot, and in the space of an hour, a deposite of moisture equal to the height of an inch. If the sum of the opposite velocities amounted to 60 miles an hour, and the intermingling influence extended but to a quarter of an inch at the grazing surfaces, there would still, on this supposition, be produced in the same time a fall of rain reaching to half an inch in altitude.

These quantities come within the limits of probability, and agree sufficiently with experience and observation. But, in the higher temperatures, though the difference of the heat between the opposite strata of air should remain the same, the measure of aqueous precipitation is greatly increased. Thus, while the mixing of equal masses of air, at the temperatures of 40° and 60°, is only 6·6, that from a like mixture at 80° and 100° amounts to 19°. This result is entirely conformable to observation, for showers are most copious during hot weather and in the tropical climates.

The quantity of moisture precipitated from the atmosphere thus depends on a variety of circumstances; on the previous dampness of the commixed portions of the fluid, their difference of heat, the elevation of their mean temperature, and the extent of the combination which takes place. When this deposition is slow, the very minute aqueous globules remain suspended, and form clouds; but if it be rapid and copious, those particles conglomerate, and produce—according to the state of the medium with regard to heat—rain, hail, or snow.

Velocity of the drops of rain.

The profuse precipitation of humidity is caused by a rapid commixture of opposite strata. The action of swift contending currents in the atmosphere brings quickly into mutual contact vast fields of air over a given spot. The separation of moisture is hence proportionally copious. In temperate weather this deposition forms rain; but, in the cold season, the aqueous globules, freezing in the mid-air into icy spiculæ, which collect in their slow descent, become converted into flakes of snow. Hail is formed under different circumstances, and generally in sudden alternations of the fine season, the drops of rain being congealed during their fall, by passing through a lower stratum of dry and cold air.

The drops of rain vary in their size perhaps from the twenty-fifth to a quarter of an inch in diameter. In parting from the clouds, they precipitate their descent, till the increasing resistance opposed by the air becomes equal to their weight, when they continue to fall with an uniform velocity. This acquired or *terminal* velocity is therefore in the sub-duplicate ratio of the diameters of the aqueous globules. A thunder-shower hence pours down much faster than a drizzling rain. In general, if d express the diameter of a drop in parts of an inch, the terminal velocity, according to theory, will be denoted by $78\sqrt{d}$, or, if the usual correction be made for the discrepancy in fluids, it will be $67\sqrt{d}$. Thus a drop of the twenty-fifth part of an inch, in falling through the air, would only gain a celerity of $11\frac{1}{2}$ feet, while one of a quarter of an inch would acquire a celerity of $33\frac{1}{2}$ feet. A flake of snow, being perhaps nine times more expanded than water, would descend thrice as slow. But hailstones are often of considerable dimensions, exceeding sometimes an inch in length. They may hence fall with a velocity of 70 feet each second, or at the rate of about 50 miles in the hour. Striking the ground with such impetuous force, it is easy to conceive the extensive injury which a hail-shower may occasion in the hotter climates. The destructive power of those missiles in stripping and tearing the fruits and foliage increases, besides, in a faster ratio than the momentum, and may be estimated by the square of their velocity multiplied into mass. This fatal energy is hence as the fourth power of the diameter of the hailstone.

III. Optical Phenomena.—It remains for us to explain the general optical appearances of the sky. When the rays of the sun strike upon a cloud, they are copiously reflected, but partly absorbed by the minute suspended globules. In working their progress through the mass of vapour, they suffer a great diminution from the multiplied acts of absorption. The quantity of light thus finally detained depends on the density of the cloud, and its thickness. But the portion which penetrates through the nebulous medium is always much less than what traverses an equal body of air. In extreme cases, perhaps, the solar beams will suffer greater defalcation by repeated repercussions within a congregated cloud, than from passing through fifty times the same extent of a clear aërial expanse. Hence such clouds always appear dark and black, by their scanty transmitted light. Whiteness, being produced by the copious emission of intermingled rays, can belong only to very thin clouds. The depth of shade indicates the mass of floating vapour.

Rainbows.

Owing to the excessive minuteness of the aqueous globules, the particles of light are only reflected or absorbed at their external surface, without entering them. But when they collect into large drops, the luminous pencil which strikes at a certain angle converges by refraction to a point of the posterior surface, and, after suffering one or more interior reflections, it emerges dissected into its primitive colours. Hence the glorious vision of the rainbow, which was reduced to mathematical calculation by Descartes, but only received its complete explication from the optical discoveries of Newton. The phenomena occur whenever the sun shines upon the falling drops of rain behind the spectator, the coloured arch being a portion of a circle whose centre is a point in the sky directly opposite to the sun. The primary or interior bow is formed by a single reflection, and lies 45° beyond that centre; but the secondary or superior bow, produced by a double reflection, appears with inverted tints at the distance of 56°. A ternary bow may exist, but being so extremely faint from the repeated reflections, it is scarcely ever perceived. It hence follows, that rainbows are only visible when the altitude of the sun is below 45° and 56°. In summer, accordingly, they are not seen in this climate about the middle of the day. For the same reason, they generally appear less than a semicircle; but viewed from the top of a spire, or any lofty pinnacle, they embrace nearly the whole circumference. Lunar rainbows may be frequently observed, only the faintness of their colours makes them far less conspicuous.

Halos.

The coloured rings or *halos* which are often seen surrounding the moon and sun, are evidently occasioned by very thin vapour diffused through the atmosphere. They are supposed chiefly to encircle the moon; but, in this climate, hardly a day passes with light fleckered clouds, when

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at least portions of halos may not be perceived near the sun. It is only necessary to remove the glare of light which makes the delicate colours appear white. Thus, if we examine the reflection from a smooth surface of water, we shall perceive that the sun gilds the fleecy clouds with segments of beautifully coloured rings. This effect is still more distinctly seen if the rays from a hazy or mottled sky be received upon a sheet of white paper, held before a small hole in the window-shutter of a dark room. But even when the sun shines from an azure firmament, circles of the richest tints may be produced by experiment. Holding a hot poker below, and a little before, the small hole of the shutter, throw a few drops of water upon it, and the sun will be painted upon the paper like the glowing radiations of the *passion-flower*. The appearance is exactly similar to what the traveller, in awakening from a short slumber, perceives, in a winter's morning, on opening his wearied eyes to a burning candle—concentric rings of violet, green, yellow, and red.

Their origin.

The explication formerly given of the cause of halos, even that proposed by Newton himself, is inadmissible; since it would confine them, like the rainbows, to certain definite limits, whereas they appear with every possible degree of extension. Our earliest inquiries led us to refer the origin of halos to the *deflection* of light, or that property of the rays to bend and divide as they pass near the edge of a body. Thus the light admitted through a very narrow slit in a card, or a bit of tinfoil, spreads into bright coloured fringes. The finer also is the slit, the broader are the fringes. A similar appearance is obtained by looking at the elongated flame of a candle through the delicate fibres of a feather, or even through the streaks of grease rubbed by the finger along a piece of glass. But if a very small round hole be substituted for the slit, the fringes will change into coloured rings. Thus, if a piece of tinfoil, punctured with the point of a needle, be held close to the eye, the sun will appear through it surrounded by a halo very near his disc, but spreading more in proportion as the hole is contracted. That ingenious artist Mr Troughton constructed for us a slide of brass, and afterwards another of platina, perforated with a series of the finest conical holes, which were measured by his delicate micrometer. The purpose was to compare the angle subtended by the coloured ring with the diameter of the perforation, it being inferred that an aqueous globule of the same dimension might, by the exterior deflection of the solar rays, produce a similar halo. But our variable sky is very seldom fit for any refined optical experiment, and many delays happening to intervene, we could arrive at no very precise or certain result. We may state, however, as at least an approximation, that the globules of the diffuse vapour which occasions the appearance of coloured circles about the sun and moon, vary from the 5000th to the 50,000th part of an inch in diameter. When the halo approaches nearest to the luminous body, the largest globules are floating, and therefore the atmosphere is surcharged with humidity. Hence the justness of the vulgar remark, that a dense halo close to the moon portends rain.

Eriometer.

Nearly the same theory has been struck out by Dr Thomas Young, to whose profound ingenuity and most extensive information we are glad to bear honourable testimony. By a skilful application of the principle of deflected light, he has likewise constructed the *Eriometer*, a curious instrument for measuring the size of the fibres of wool and other filamentous substances. But we cannot at present enter into the details.

Parhelia.

The same acute philosopher has given perhaps the only true account of the origin of the *parhelia* or *mock suns*, which are frequently seen in the arctic regions during certain dispositions of the atmosphere. This gorgeous appearance of intersecting luminous arches, studded with opposite and transverse images of the sun, he ascribes to the combined reflections of the rays from the natural facets of the snowy *spiculæ* floating abundantly in the air.

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Another most remarkable optical deception occurs in a peculiar state of the atmosphere on the verge of the horizon in various countries, and especially in the warmer climates, whether on the level plains, or on the margin of rivers or lakes, and near the sea-shore. In such situations the remote objects often appear with extraordinary elevation, and in double or inverted images. This singular phenomenon is obviously caused by the irregular refractions which the rays of light occasionally suffer by passing through the different strata of the lower atmosphere. When the effect is confined to the apparent elevation of an object, our seamen call it *looming;* but if inverted images be formed, the French and Italians give to this play of vision the appellations of *mirage* and *fata morgana*. The shipping and range of buildings on the shore of Naples have from Messina sometimes appeared floating inverted in the air. In the autumn of 1798 the coast of France was distinctly seen raised above the sea, from the beach of Hastings; the appearance lasted about an hour, and then sunk beneath the horizon. In the following year, Professor Vince watched the phenomena at Ramsgate with a large telescope. On the afternoon of the 1st of August he first descried the sails of a ship, but as she came fuller in view, he perceived another inverted image just below the surface of the water. Fig. 16, Plate CCCLV. represents the successive appearances; A is the ship when first observed, C after she had approached, and B the inverted image. Fig. 17 exhibits a variation of the effect; *a* marks the ship entering the horizon, C and B the double image of the ship when near, a portion of the sea lying between its opposite traces. To produce the appearances now represented, it was quite requisite that the rays of light, in traversing the lower strata of the air, should describe curves, whose final tangents point in the visual directions of the objects. These curves or trajectories are delineated in fig. 13, where E marks the place of the observer, *zb* the horizon, *b* the hull and *a* the mast of the ship; the lowest image is formed by the curves *bs*E and *ar*E; above this the curves *bv*E and *aw*E give an inverted image, and the curves *bn*E and *am*E exhibit the highest erect image.

Phenomena of irregular horizontal refraction with extreme obliquity.

Observations of Vince.

In ordinary cases, a ray of light, in crossing different layers of the atmosphere, describes a trajectory, which is nearly the portion of a circle, having six times the diameter of the earth. The rate of inflection is proportional to the tangent of obliquity, and to the difference of the refractive power of the conterminous strata, which may be assumed as the same as their difference of density. This variation in a stratum of air twenty-eight feet thick is only the thousandth part of the whole refraction, and is hence equal to the effect of the quarter of a centesimal degree. But since a much greater difference of heat often occurs within that limit, the incurvation of the trajectory must be proportionally increased. Humidity, by dilating the air, will produce a similar effect, though in a much inferior degree, unless in very high temperatures.

Experiments of Wollaston.

Dr W. H. Wollaston, whose acuteness in devising philosophical experiments was unrivalled, exhibited on a small scale the various appearances occasioned by irregular atmospheric attraction. His paper inserted in the Philosophical Transactions for the year 1800 contains a very clear exposition of the phenomena. On looking lengthwise over the side of a red-hot poker at a distant object, besides the ordinary image, another inverted one was seen within the edge of the streaming air, and a larger erect one still nearer the poker, as represented in fig. 14. The deviation was here only half a degree; but along a red-hot bar of iron, the separation of the images was increased to

Meteoromancy || Methodists.

a degree and a quarter. On directing the eye over the surface of a green board, which had been heated by exposure to the sun, a double image was distinctly seen. Another board, merely wetted with water, betrayed a similar disposition, though it was very difficult to distinguish the irregular image, its elevation being only 3′. But on moistening the surface of the board with alcohol, the images were easily seen at a separation of 15′. Still more conspicuous was the appearance on spreading a little ether over a plate of glass, for the irregular image showed itself $7\frac{1}{2}°$ raised.

His illustration.

It was easy to imitate and examine the natural phenomena by means of a square parallelopiped composed of plate glass. Having filled the half of this with cold water, let hot water be gently poured over it, and the cover placed upon the top. (See fig. 15, Plate CCCLV.) On standing a few feet behind the parallelopiped, and looking at distant objects through the stratum where the cold and hot water have become blended, the double and inverted images will for a short time be clearly perceived. But a more durable effect is obtained by filling one third of the glass case, as represented in fig. 15, with syrup or a strong solution of white sugar, another third with distilled water, and the rest with pure alcohol. A mutual penetration slowly takes place between the conterminous surfaces of the alcohol A and the water B, and between this and the syrup C; and after the lapse of perhaps two or three days, the blending spaces become sufficiently broad for observation. The appearances then are nearly such as those that have been sketched in the plate.

This mode of experiment is at once simple and convincing. The theory which Dr Wollaston draws from it is equally ingenious, but not so demonstratively established as its author presumes. It rests chiefly on the supposition, that the stratum occupied by the penetration of two fluids of different densities, graduates in refractive intensity more slowly at its boundaries, and most rapidly in the middle. Or, to borrow the elucidation of geometry, if the successive densities be denoted by ordinates, their summits will form a line of double curvature, having consequently a point of contrary flexure. This principle may be sound, though we can perceive no cogent reason why the curve of intermediate refraction should be convex or concave, or should combine both sorts of incurvation. But admitting this double curvature to be a constituent law, it will very satisfactorily explain the phenomena. The refraction will be the same as if the light had traversed an uniform medium bounded by a surface of that reverted curvature, the convex portion diverging, and the concave portion converging, the parallel rays. The different effects are exhibited in fig. 12; the distant object O is viewed in its true position by the pencil that arrives at O; it is seen inverted at I, by the rays which enter at *m*; the rays which fall on *r* make it appear again erect at A. This explication is certainly very plausible, and may probably approximate to the truth. But though much has been already achieved, the subject of irregular refraction needs to be revised, and still more closely investigated. (B.)

Methodists.

His explication.

For some further illustrations of the subject of this article, see Barometer, Climate, Cold, and Weather.

METEOROMANCY, a species of divination by meteors, principally by lightning and thunder.

METESSIB, an officer among eastern nations, who has the care and superintendence of all the public weights and measures.

METHEGLIN, a species of mead. The word is Welsh, in which language *meddyglin* signifies the same thing.

METHOD, the arrangement of our ideas in such regular order that their mutual connection and dependence may be readily comprehended. See Logic.

METHODISTS, a numerous religious body both in this country and in America. They are divided into several distinct sects; but from the minute shades by which these are distinguished, and the extreme obscurity of some of their numbers, it is difficult to furnish a perfectly accurate account of them. We shall describe those which are best known.

Wesleyan Methodists.

The first in order of time, as well as in point of numbers, is that of *Wesleyan Methodists*. This body derives its name from its principal founder, the Rev. John Wesley. Whilst a student at Christ-Church College, Oxford, and engaged in the pursuit of theology, as preparatory to his entering into deacon's orders, Wesley's mind had become strongly imbued with that peculiar asceticism which colours the writings of Thomas a Kempis, Fenelon, William Law, and occasionally of Jeremy Taylor, of whose works he had been a diligent and admiring student. On his assuming the sacred office, this tendency was increased rather than diminished; and when, after officiating as curate to his father, who was a clergyman in Lincolnshire, for about two years, he returned to Oxford to resume his duties as a fellow of Lincoln College, it was apparent that it had acquired the complete ascendency over his mind. His condition at this time was distressing. He felt himself burdened under a sense of guilt in the sight of God, and ignorant of the only way in which that burden could be relieved. Sympathy of feeling and unity of opinion led him to enter into an association which had been formed during his absence among a few of his former friends, in whom a similar course of discipline had produced similar effects. Of this society he soon became the leader and most active member, employing the resources of his comprehensive mind for the regulation of their meetings, and setting an example of diligence in the discharge of every office, and of patience in the endurance of every penance, which in their misguided zeal they had instituted among them, in the hope of thereby obtaining the divine favour. The regulations which they had adopted for the guidance of their conduct were unusually severe: they were in the habit of partaking of the sacrament every week; they were abstemious in their diet, and plain in their clothing; they had set hours for reading Thomas a Kempis, with meditation and prayer, and for musing on the Passion; they spent much of their time in visiting the prisons and the hospitals; they observed rigidly all the fasts of the English church, besides a constant abstinence on Wednesdays and Fridays; and in several other respects they exhibited the hold which a morbid asceticism had acquired over their minds. By such conduct, while they commanded the respect of a few, they became the object of ridicule and derision to the many, and had to run the usual gantlope of jokes and nicknames which is destined for all, especially at an university, who are audacious enough to be guilty of innovation either in politics or religion. Of the various titles which the wits of the university devised for them, the only one that has adhered to them is that by which they are now distinguished, viz. Methodists. The author of this appellative is said to have been a fellow of Merton College, who, observing the regularity with which they divided their time among their different pursuits, exclaimed, "Here is a new sect of Methodists sprung up;" alluding to the ancient Methodici, or College of Physicians, at Rome, of whom an account is given by Celsus in the preface to his work *De Medicina*. At this time their members amounted to fifteen, most of whose names Wesley has preserved in his journal. Among the rest are those of James Hervey, the author of

Methodists.

the Meditations; and George Whitefield, for some time the most efficient assistant, and subsequently the most powerful rival, of Wesley.

The regular formation of this society took place in the year 1729. During the three following years it maintained its ground under the energetic guidance of its head, and increased to the number of twenty-five. In the course of the year 1733, however, Wesley being frequently absent from Oxford, his associates began to lose heart, and to shrink from the persecution which continued to assail them; so that, on his return from a visit he had paid to Manchester and other places in that year, he found the members reduced to five. Grieved, but not disheartened, he immediately set himself to repair the loss, but with what success does not appear. His exertions, however, were so great, that, combined with his abstemiousness, they began seriously to affect his health. It is probable that this, together with other circumstances of a private nature, combined with his religious zeal to induce his acceptance of an offer made to him by the trustees of the new colony of Georgia, to go out as one of the chaplains of that settlement. This offer was made about the middle of 1735, and towards the close of that year he left England, accompanied by his brother Charles and two other of his Oxford associates, in order to enter upon the duties of his office. On his voyage out he became acquainted with David Nitschman, a Moravian bishop, who, with a party of his followers, was proceeding in the same vessel to join a colony of their brethren already established in the new settlement. From this individual he derived no small advantage in a religious point of view; nor was the insight which he thus obtained into the Moravian institutions and polity without service to him, when, in subsequent years, he had to assume the office of arranging and legislating for a party of his own.

But Wesley's connection with the Georgian colony was not of long continuance. It was dissolved in 1737, and, in the month of February of the following year, he arrived in London, a wiser if not a better man than when he had set out. A few months of irregular occupation followed his return; but in September of that year he commenced that course of life in which he persevered till his death, and in the pursuit of which he visited personally the principal places, not only in England, but also in Ireland and in Scotland. The example of his friend Whitefield first induced him to commence field-preaching; a practice which he followed ever afterwards with great success. His brother Charles, who had followed him from America, became a zealous and able coadjutor; and others were speedily added to them. No systematic plan of itinerant preaching seems to have been at first contemplated by them; but their exertions in one place led to their visiting another, and thus a regular course of occasional ministrations was gradually adopted. At first both Wesley and his brother were decidedly opposed to lay-preaching; but the difficulty, or rather the impossibility, of finding individuals who had received orders to supply their rapidly increasing stations, combined with the evidence furnished by one or two remarkable examples, of the possibility of successfully employing individuals who had not been regularly educated for the ministry, in itinerant preaching, led to the ultimate adoption of this as a part of their ecclesiastical machinery. An extensive agency was thus called into operation, by which the Wesleys were enabled to bear in upon the mass of the people throughout the country, and in consequence very widely to diffuse their principles, and augment the number of their adherents. By what steps they advanced it is impossible accurately to detail; but in a very few years they had succeeded in overcoming the persecution by which at first they were everywhere assailed, and in forming societies in all the principal towns and larger villages of England. Over all these Wesley maintained a vigilant watchfulness; and though in general lenient and patient, he yet visited with rigorous discipline those communities or preachers by whom any flagrant departure from the accredited doctrines or practices of the body had been committed. His influence among the societies was maintained partly by frequent visitations, and partly by the power which was concentrated in an annual convention of the preachers, called the Conference, of which he was the moving spring. The first meeting of conference was held in 1744, and this body has regularly held its meetings ever since.

Methodists.

Before Wesley's death, Methodism had obtained a considerable footing not only in England and Wales, but in Ireland, America, the West Indies, and to a limited extent also in Scotland. At the time of his death "the number of members in connection with him in Europe, America, and the West India Islands, was 80,000."[1] Since that time this denomination has been making a steadily increasing progress. At the Conference of 1836, the numbers returned were, in Great Britain 293,132; in Ireland 26,434; in the Foreign Missions 61,803; in Upper Canada 16,092; under the care of the American Conferences 652,528; total 1,049,989. The number of preachers throughout the world is 4273. Foreign missions have been established in various parts of Europe, Asia, Africa, and America, including the West Indian, Polynesian, and Australasian Islands. An important branch of these missions is the schools which are attached to the different stations, and which are conducted by the missionaries themselves, or under their immediate superintendence. The sum raised for these purposes at the close of the year 1835–36 was L.70,996. 1s. 11d.

The *doctrines* taught by Mr Wesley and his preachers may be technically described as those of Evangelical Arminianism. In regard to all the positive doctrines of Christianity, he assented, with a few modifications, to the standards of the reformed churches. He maintained the depravity of human nature; the necessity of an atonement for sin before it can be forgiven; the doctrine of a divine influence to lead men to Christ; justification by faith alone; and the importance of good works, not as the ground of acceptance with God, but as the evidence of faith, and the measure of the final reward. He differed from the system of Calvin chiefly in regard to the extent of the atonement, which he maintained was for all men; to the doctrine of a common grace, which he supposed was given to all, though in various degrees and in different ways;[2] to the opinion that a man who had once believed the gospel might relinquish his belief, and so perish; and to the notion that Christians might obtain salvation from all sin, or entire sanctification, before death. He also held that repentance, which he defined to be "conviction of sin, producing real desires and sincere resolutions of amendment," and fruits meet for repentance, preceded faith; and that the believer has not only the testimony of his own consciousness to persuade him that he is justified, but also the direct testimony of the Spirit of God. These opinions are still retained by the Methodist body.[3]

Of the *polity* of Wesleyanism, the fundamental principle is, that all power is centred in the Conference or annual convention of the clergy. From this body all authority emanates, and by them all regulations to be observed throughout the society are devised and appointed. In

[1] Watson's Life of Wesley, p. 378.
[2] See this tenet defended at length in Watson's Theological Institutes, vol. ii. p. 258–263.
[3] Watson's Life of Wesley, p. 168–199.

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their name also are levied all the funds that are required for carrying on the operations of the society, of appointing the individuals who are to superintend the different sections into which the denomination is divided, of assigning to each preacher the station he is to occupy, and of suspending or excluding any member of the community, whom a subordinate jurisdiction, entitled a Leader's Meeting, may have found guilty of certain faults. All their deliberations being carried on with closed doors, the people at large have no check on their decisions, nor any means of controlling their power: the results of their discussions, however, are published, after each meeting, under the title of Minutes. The management of the body is thus vested entirely in an oligarchy of clergymen, self-elected, and all but entirely uncontrolled. The security of this system is perpetuated by the careful gradation of rank which obtains throughout the whole body of functionaries. The supreme power being vested in Conference, the whole field of Methodism is divided into distinct departments, to which is given the name of Circuits. To each of these as many preachers are appointed as its exigencies may require, and at their head is placed one whose experience and reputation, but especially his fidelity to the cause of Conferential supremacy, entitle him to the distinction, and to whom, under the name of Superintendent, the charge of the whole circuit is committed. The appointment of these functionaries is made annually; and no preacher or superintendent can be re-appointed to the same place for more than three years successively. Besides these, each circuit has its local preachers, who are generally persons engaged in secular business, but who, having by zeal and ability obtained for themselves the approbation of a Local Preacher's Meeting, are permitted by the superintendent to preach, throughout the vicinity of the place where they reside, in private houses and small country chapels. Out of the number of these the regular preachers are generally chosen, as they have been themselves for the most part chosen from amongst the Class-leaders or superintendents of the portions into which each congregation is divided. These classes consist generally of twelve members, and it is the duty of the leader to visit, instruct, and exhort them, as well as to collect their contributions to the funds of the society, and to watch over the correctness of their general conduct. At the meetings of these classes the members state their religious experience, and confess their faults to one another. This, however, is more particularly the object of another subdivision (connection with which, however, is not deemed imperative) called Bands: the members of these are all of one condition in life; that is, the married males meet in one Band, the married females in another, and so on. In these Bands, which are also under the charge of Leaders, there is, in consequence of this arrangement, more freedom of communication, especially in regard to besetting sins and peculiar temptations. Another portion of the members are engaged in the duties of Sunday-school teachers, and are also under the superintendence of a leader. Over all these different agencies it is the duty of the circuit superintendent to watch; and to all of them his word is law. An appeal, indeed, lies from his decisions to Conference, but experience has so abundantly shown the uselessness of all such appeals, except in cases of the most glaring nature, that they are hardly ever made.

Whatever objection may be brought against the complication of the machinery of Methodism as opposed to the simplicity of the New Testament, this should not prevent our doing justice to Wesley and his followers, by admitting the importance of the services which they have rendered to the cause of religion, education, and morality, throughout the empire. By no denomination of Christians, perhaps, have greater benefits been conferred, in these respects, on the nation at large, than by the Wesleyans. Impelled by an undaunted zeal, they have visited the most abandoned, and instructed the most ignorant, of the population. Wherever they have gone they have carried the elements of a renovated state of society with them, in the doctrines they have taught and the duties they have inculcated. In many parts of England, where, before they commenced their labours, the truths of Christianity were as little known as they are in heathen countries,[1] they have succeeded in raising large and active communities, amongst which the effects of Christian teaching are apparent, in the good conduct, comfortable circumstances, and increasing respectability of those by whom they are composed. Their zeal has also operated beneficially on other denominations, and has called forth energies that, but for the stimulus of their example, might have continued to lie dormant. In short, it must be confessed, that England and America owe an immense debt of gratitude to the illustrious founder of this powerful society; and that the loss of Methodism would be a loss to the world.

Metho-dists.

Next in order to the Wesleyan Methodists are the *Calvinistic Methodists.* Under this term are included three distinct connections, all of which, however, either arose from, or were greatly strengthened by, the exertions of Whitefield, the original companion of Wesley; and from that circumstance they are sometimes ranked under the name of *Whitefieldians.* Whitefield separated from Wesley shortly after the time when the latter commenced his regular labours as a preacher, upon his return from America. The cause of their separation was their having espoused opposite sides of the Arminian and Calvinistic controversy; Wesley ranking himself with the adherents of the former class of opinions, and Whitefield with those of the latter. This led to their carrying on their itinerant labours independently of each other, though without any attempt on either side to interrupt the peace or the usefulness of the other. Whilst Wesley, however, was skilfully availing himself of his success for the purpose of forming a sect, Whitefield, with less worldly wisdom, contented himself with merely preaching from place to place, and associating himself with any who would acknowledge him as a minister of Christ. At several places, indeed, where he had attracted much attention by his powerful and (to judge from the effects) unparalleled eloquence, he erected chapels, or tabernacles as he called them; but these he invariably left to the care of any evangelical clergymen, whether in the establishment or among the dissenters, whom he saw raised up to occupy them. Since his death, the members of these congregations have been nominally, and only nominally, classed together as a distinct body, under the name of the *Tabernacle Connection.* In some of these congregations the service is conducted according to the ritual of the church of England, whilst in others the order of worship is more in accordance with that observed by the Independents. They all, however, agree in this, that whether there is a settled minister in the place or not, a succession of supplies from the country is kept up throughout the year, each minister being engaged for a month or six weeks at a time. Where there is no settled pastor, the "supply" for the time being discharges the whole duty of the place; where there is a settled pastor, the duties are divided between them. The members of this connection have of late years been gradually verging towards the Independents, and it is probable that in a short time both bodies will coalesce.

Calvinistic Metho-dists.

Amongst the most zealous and devoted of Mr White-

[1] "He (Wesley) found thousands of his countrymen, though nominally Christians, yet as ignorant of true Christianity as infidels or heathens." (Bishop Coplestone, as quoted in Watson's Life of Wesley, p. 313.)

Methodists.

field's adherents was Selina, countess of Huntingdon, in whose family he at one time officiated as chaplain. After the death of her husband she employed her ample resources in the erection of chapels in different parts of the country, to the occupation of which she invited at first none but regularly ordained clergymen of the Episcopal Church. Many such accepted her invitation, and laboured in the places she had erected; but finding the supply from this source not adequate to the demand, she founded a college at Trevecca, in South Wales, for the education of pious young men of talent for the university. By these means a distinct party was formed, which assumed her name, and is known as *Lady Huntingdon's Connection*. They have about sixty congregations, in all of which the service is conducted strictly according to the ritual of the established church. The college has been removed, since the death of its foundress, to Cheshunt in Hertfordshire, where it is now in a flourishing state.

Another body, which, though not founded by Mr Whitefield, was much strengthened through his means, is that denominated the *Welsh Calvinistic Methodists*. The original founder of this body was Mr Howel Harris, of Trevecca. This gentleman had intended to take orders in the church of England, but was turned from his purpose by what he witnessed amongst the students at Oxford, who seemed to him wholly given to folly and impiety. On his return home he began to preach to his neighbours and in the surrounding parishes. This took place in 1735, and excited no small attention; numbers collected in every place where he preached, to hear him; and, ultimately, societies were formed, which were placed under the superintendence of experienced individuals. The preaching of Mr Harris was not only successful among the people at large, but was also followed by several clergymen, who at length gave up their livings, and united themselves with him. To this party Mr Whitefield lent the aid of his powerful eloquence, and in return received from it many of his most zealous preachers. It was not, however, till the year 1785, when it was joined by the Rev. Thomas Charles of Bala, that, owing mainly to the exertions of that individual, it was organized into a regular body. Since that time its numbers and resources have been steadily increasing, both in North and South Wales. It is said that there is hardly a village in the principality where one of its chapels is not to be found. The doctrines held by its members are those of high or hyper-calvinism. Their form of church government inclines to the presbyterian, though many practices are encouraged among them that presbyterians in general would condemn, such as the utterance of exclamations of desire or exultation on the part of the audience during public prayer, jumping and throwing themselves into violent postures under the excitement produced by the preacher's address, and others of a similar kind. They admit also of lay-preaching, and some of their most popular orators are of this class. The sermons of their preachers are generally delivered in a slow recitative, interrupted by quick and startling appeals and interrogations. Even upon those who are ignorant of the language in which the address is uttered, this peculiar mode of delivery is productive of a powerful sensation. It is not surprising, therefore, that on those by whom the whole is understood, and who can enter fully into the highly figurative and impassioned style of sentiment in which the Welsh preachers generally indulge, the most singular effects should be produced. It is no unusual thing to see whole congregations convulsed, and thrown into the most violent agitation, almost instantaneously, by some well-managed appeal to their feelings on the part of the preacher; and this once accomplished, it is not very difficult to keep up the excitement, until both speaker and hearers are ready to sink to the ground from pure exhaustion. The prevalence of this habit cannot but be regretted; but it is characteristic of the people, and though it is doubtless productive of much that is injurious to true piety, it cannot be questioned, that, upon the whole, the labours of these preachers have told most beneficially, as well as extensively, upon the religious and moral improvement of their countrymen.

Methuselah || Metonymy.

Other Methodists.

The other classes of Methodists have been produced by secessions from the great body of Wesleyan Methodists. The reason assigned for these secessions has been nearly the same for all, viz. the arbitrary and unconstitutional power assumed by the Conference. The only exception to this is in the case of the *Primitive Methodists*, or *Ranters*, whose ground of secession was, that the true spirit of Methodism was no longer kept up in the body. By this they meant that too much attention was paid to order and decorum in the conduct of public worship; and that sufficient zeal was not manifested in obtruding religion upon the minds of the people by street-services, field-preaching, &c. They are fond of doing nothing in a corner, and, accordingly, often parade the streets, singing hymns and inviting the populace to their places of worship. They also admit of females being allowed to preach. The number of their chapels is about 400; that of their preachers 2700; and that of their members 33,720.

The first secession upon the ground of the unscriptural power exercised by the Conference (and the earliest in point of time of any of the secessions), was made by a party in 1797, very soon after Mr Wesley's death. At the Conference held at Leeds that year, delegates appeared from many of the societies throughout the country, who were instructed to request that the people might have a voice in the formation of their own laws, the choice of their own officers, and the distribution of their own property. These reasonable demands having been refused, the petitioners agreed to secede from the Conference connection, and to form themselves into a distinct party, upon a more liberal basis. The person who took the largest share in prompting and providing for this step was Mr Alexander Kilham, and from him the body thus formed have taken the name of *Kilhamites*. They also style themselves the *New Connection Methodists*. Their doctrinal views are those of Wesley, but in their polity they seem to have followed in a good measure the forms of presbyterianism as exhibited in Scotland. The people choose their officers, and appear by representatives at all the synodical meetings of the denomination. This party is not very numerous. In 1829 they had 162 chapels, fifty-nine circuits, 492 local preachers, and about 11,780 members.

Of late there have been several considerable secessions from the general body of the Wesleyans. At least *four* distinct parties have been formed within a few years. These are the *Bryanites*, so called from a Mr Bryan, their founder; the *Independent Methodists;* the *Wesleyan Protestant Methodists;* and the *Warrenites*, or followers of Dr Warren. A proposal has, it seems, been made to unite these parties under some common name, all having seceded on nearly the same fundamental grounds, and all holding the same leading principles.

See Southey's *Life of Wesley;* Watson's *Life of Wesley;* Gillies's *Life of Whitefield;* Bogue and Bennet's *History of Dissenters*, vol. iii.; and Buck's *Theological Dictionary*, by Henderson.

METHUSELAH, the son of Enoch, and father of Lamech, was born in the year of the world 687; he begat Lamech in 874, and died in 1656, at the age of 969, the greatest age which has been attained to by any man upon earth.

METŒCI, a name given by the Athenians to such as had their fixed habitations in Attica, though by birth they were foreigners.

METONYMY, in *Rhetoric*, is a trope in which one

Metope ‖ Meursius.

name is put for another, on account of the near relation that subsists between them.

METOPE, in *Architecture*, is the interval or square space between the triglyphs of the Doric frize.

METOPOSCOPY, the pretended art of knowing a person's dispositions and manners by viewing the traces and lines in the face.

METRE, in *Poetry*, a system of feet of a just length. The different metres in poetry are the different modes of ordering and combining the quantities, or the long and short syllables. Thus hexameter, pentameter, iambic, and sapphic verses, consist of different metres or measures. In English verses, the metres are extremely various and arbitrary.

METRETES, a Grecian measure, containing something more than nine English gallons.

METRICAL Verses, are verses consisting of a determinate number of long and short syllables, as those of the Greek and Latin poets.

METROCOMIA (from *μητηρ*, *mother*, and *κωμη*, *town* or *village*), a term in ancient ecclesiastical history, signifying a borough or village which had other villages under its jurisdiction.

METRONOMII, the name given by the Athenians to five officers in the city and ten in the Piræus, whose duty it was to inspect all sorts of measures excepting only those of corn.

METROPOLIS (from *μητηρ*, *mother*, and *πολις*, *city*), the capital of a country or a province; or the principal city, and, as it were, the mother of all the rest. The term *metropolis* is also applied to archiepiscopal churches, and sometimes to the principal or mother-church of a city. The Roman empire having been divided into thirteen dioceses and a hundred and twenty provinces, each diocese and each province had its metropolis or capital city, where the proconsul had his residence. To this civil division the ecclesiastical was afterwards adapted; the bishop of the capital city having the direction of affairs, and the preeminence over all the bishops of the province. His residence in the metropolis gave him the title of *metropolitan*. The erection of metropolitans is referred to the end of the third century; it was confirmed by the council of Nice.

METZ, an arrondissement of the department of the Moselle, in France, extending over 664 square miles. It is divided into nine cantons, and these into 275 communes, and it contains 136,500 inhabitants. The city of Metz, the capital of the department, as well as that of the arrondissement, is situated on the river Moselle, where the Seille falls into that stream, and becomes navigable. It is divided into two branches, one of which washes the walls of the city, and the other divides it into two parts. The Seille passes the city on the south and east sides, and then falls into the Moselle. Metz is one of the strongest fortified cities of France, and is defended by a powerful quadrangular citadel on the south side. The situation is fine, being surrounded with gentle elevations, forming a circle, the sides of which are covered with vineyards and fruit-trees. It has several institutions for education, especially a united college for the instruction of officers of engineers and artillery. There are sixteen churches; and it is the see of a bishop. The cathedral is of Gothic architecture, of prodigious extent, and has a tower 360 feet in height. Some of the other public buildings are large, but in a very antique style, as are the greater part of the private dwellings. The city contains 5850 houses and 43,400 inhabitants, exclusively of the garrison. There are in it manufactories of coarse cloths, flannels, and blankets; of sail-cloth and other linen goods; besides distillers, paper-makers, and hat-makers. Long. 6. 5. 8. E. Lat. 49. 7. 10. N.

MEURSIUS, John, one of the most laborious of antiquaries, was born in the year 1579, at Losdun, a town near the Hague. It appears that the name of his family was *De Meurs*, which he latinized, according to the usage of the learned of his time. His father, a regular canon of the house of the Twelve Apostles at Utrecht, having embraced the reform of Calvin, took refuge in 1569 at the Hague, and some time afterwards obtained the pastoral charge of Losdun. He taught his son the principles of the Latin language, and then sent him to study at Leyden, where he made so rapid progress, that, at the age of twelve, he composed harangues in Latin, and, at thirteen, verses in Greek. His taste led him to cultivate philology; he particularly directed his attention to Lycophron, the most obscure of all the Greek authors, whom he undertook to illustrate; and, at the age of sixteen, he completed his commentary on that difficult writer, a work which astonished the greatest scholars and critics of the time. When he had finished his course of study, the grand pensionary Barneveld confided to him the education of his sons; and he was also appointed to accompany them to the different courts of Europe. He turned his travels to account, by availing himself of the opportunities which they afforded for extending his knowledge; and, in passing through Orleans in 1608, he was admitted doctor of laws. On his return to Holland, he was, in 1610, appointed professor of history in the academy of Leyden; and the following year he was promoted to the chair of Greek, which he filled with great distinction. The states of Holland conferred on him the title of historiographer to their high mightinesses, and honoured him with other marks of their esteem; but after the execution of the unfortunate Barneveld in 1619, the persecution soon extended itself to all who had been in any degree connected with him; and Meursius, the most gentle of human beings, who, from his habits, was an entire stranger to the disputes which then agitated his unfortunate country, did not escape molestation. As his simple and retired life did not afford his enemies any pretext for accusing him, they attempted to drive him from his professorship by insults, which were daily repeated, even in the apartment where he delivered his prelections; they reproached him with writing too many books, and alleged that, in consequence, the university did not reap any benefit from his studies. The interests of his family, which depended entirely on the emoluments of his office, forced him to submit in silence to these affronts; but the king of Denmark having, in 1625, offered him the chair of history in the university of Sora, together with the place of historiographer, he at once accepted the situation, and fully justified the high opinion which foreigners had conceived of his talents. The remainder of his life was divided between his official duties and literary pursuits; and he died of the stone, on the 20th of September 1639, at the age of sixty. He was buried in the principal church of Sora, in a tomb adorned with an epitaph, which may be found in the *Bibliotheca Belgica* of Foppens, and also in the work of Niceron.

Meursius rendered an unappreciable service to letters by the numerous editions which he published of the Greek authors, with corrections, critical remarks, and Latin versions. The principal works which he edited are, the Poems of Lycophron; the Tactics of the Emperor Leo; the *Opuscula* of Hesychius; the Elements of Music by Aristoxenes; the Letters of Philostratus; the *Historia Lausiaca* of Pallades; the Annals of Manasses; the History of Theodosius Metochites; the Tactics of Constantine Porphyrogennetes; the Marvellous Histories of Phlegon Trallianus, Antigonus Carystius, and Apollonius Dyscoles; and the works of Porphyry, Procopius, Gaza, and others. The works of Meursius were collected by Lami, Florence, 1741–1763, in twelve volumes folio. This collection is rare and much prized. In the *Mémoires* of Niceron (tom. xii. and xx.) will be found a list of all the productions of this indefati-

Meursius.

Meurthe.

gable writer, in number sixty-seven; but we shall here only indicate those which are most deserving of the attention of the curious. I. *Glossarium Græco-Barbarum*, Leyden, 1614, in 4to; a work which, in regard to the Greek writers of the Lower Empire, holds the same place as the Glossary of Du Cange does for the writers of the corresponding age of Latinity. II. De Funare liber singularis, in quo Græci et Romani ritus explicantur; De Puerperio Syntagma, Hague, 1604, in 8vo; Roma Luxurians, sive de Luxu Romanorum, Leyden, 1631, in 4to; De Populis Atticæ liber, 1616, in 4to; Atticarum Lectionum libri vi. 1617, in 4to; Orchestra, sive de Saltationibus Veterum, 1618; Græcia Feriata, sive de Festis Græcorum, 1619; Panathenæa, sive de Minervæ Festo genuino, 1619; Eleusinia, sive de Cereris Eleusinæ sacro et festo, 1619; De Tragœdiis Græcis, 1619, in 4to; Archontes Athenienses, 1622; Fortuna Attica, seu de Athenarum origine, 1622; Cecropia, seu de Athenarum Arce, 1622; Græcia Ludibunda, sive de Ludis Græcorum, 1622, in 8vo; Pisistratus, sive de ejus liberorumque Vita et Tyrannide, 1623; Areopagus, sive de Senatu Areopagitico, 1624; Athenæ Atticæ, sive de præcipuis Atheniensium Antiquitatibus, 1624; Denarius Pythagoricus, 1631, in 4to; Solon, sive de ejus Vita, Copenhagen, 1632, in 4to; Regnum Atticum, Amsterdam, 1633; Theophrastus, sive de illius libris qui injuria temporis interciderunt, Leyden, 1640, in 12mo; Miscellanea Laconica, Amsterdam, 1641, in 4to; Ceramicus Geminus, sive de Ceramici Atheniensis utriusque antiquitatibus, Utrecht, 1662, in 4to; Creta, Cyprus, Rhodus, sive de Insularum rebus et antiquitatibus, Amsterdam, 1675, in 4to; Theseus, sive de ejus Vita, Utrecht, 1684; Themis Attica, sive de Legibus Atticis, 1685; De Regno Laconico, 1687. III. Rerum Belgicarum liber primus, de Induciis belli Belgici, 1612, in 4to, very rare. IV. Athenæ Batavæ, sive de urbe Leydensi et academia, Leyden, 1625. V. Historia Danica, usque ad annum 1523, Copenhagen, 1630, in 4to. The historical works of Meursius were collected and published at Amsterdam, 1638, in folio.

The memory of Meursius has suffered by his being sometimes represented as the author of the infamous dialogues *De Arcanis Amoris et Veneris*. This licentious work, it is now well known, was the production of one Chorier, an advocate of Grenoble, who probably prefixed to it the name of Meursius for the purpose of throwing ridicule on the grave and learned professor. His son John was a scholar of considerable eminence, and produced some works evincing erudition and research. (A.)

MEURTHE, a department of France, formed out of the ancient Toulois and a southern portion of Lorraine. It extends in east longitude from 5. 30. to 7. 12. and in north latitude from 48. 31. to 49. 7., being in extent 2602 square miles, or 643,800 hectares. The appropriation of the land is as follows: 242,288 hectares are arable, 227,197 consist of woods and forests, 69,140 are pastures and meadows, 14,712 vineyards, and the remainder is either roads, rivers, lakes, the sites of towns and villages, or uncultivated. It is not a mountainous, but a hilly district, interspersed with valleys of moderate fertility. None of the hills are more than 600 feet above the level of the sea, though some spurs of the Vosges Mountains, on the border of the department, attain a greater elevation. The subsoil is generally calcareous, but in some parts consists of gypsum, and is covered with a mixture of clay, sand, and pebbles. It is fertile upon the whole, and produces more wheat and rye than is required for home consumption, especially since the extension of the growth of potatoes has made that food a substitution for grain with the more indigent part of the population. The water of the department passes either into the Moselle or the Meuse, which are alone navigable. The Meurthe gives name to the department. The climate is cold and variable, but not unhealthy. The inhabitants are a hardy and active race, amounting to 370,500. In the cities and towns the French language is spoken; in the country a very disagreeable patois is used; and on the eastern side of the department a corrupt German is the common language. The greater part of the people adhere to the Roman Catholic church, but there are several consistories of both Lutherans and Calvinists; and in Nancy there are many Jews. The principal exports are wood and salt; of the latter about 34,000 tons are made annually. There are some manufactories of glass, pottery, iron, paper, seed-oil, and many distilleries and breweries; and some woollen and cotton goods are also manufactured. The capital is Nancy. The department sends three deputies to the legislature, and is divided into five arrondissements, twenty-nine cantons, and 718 communes.

Meuse ‖ Mewing.

MEUSE, a department of the north of France, formed out of the ancient provinces of Verdun, Barois (at one time called Lorraine), and Clermont. It extends in east longitude from 4. 42. to 5. 47. and in north latitude from 48. 29. to 49. 42. It is bounded on the north by the Ardennes, the duchy of Luxemburg, and the department of the Moselle; on the east by that of the Moselle and Meurthe; on the south by the Vosges and Upper Maine; and on the west by the Maine departments. It extends over 2517 square miles, and is divided into four arrondissements, twenty-eight cantons, and 591 communes. The population amounts to 284,700 persons, who all adhere to the Roman Catholic church. The whole department is hilly, and the northern part mountainous. In the valleys and the plains, which are few in number, there is moderate fertility, but nearly the half of the surface is covered with woods; and it yields barely sufficient corn for the consumption of the inhabitants. The cultivation of the vine has been of late extending, and wine of tolerably good quality is produced. The principal river, the Meuse, is a small stream, which passes through the department, and only becomes navigable when it enters that of the Ardennes. The Aire, the Aisne, the Ornain, and the other rivers, fall into the Marne. The climate is dry and healthy, but much more temperate on the south than on the north part. Some woollen and cotton goods are manufactured; but the most important branch of industry consists of the working of iron mines, and in reducing the ore. These mines are said to yield 6600 tons of cast iron and 4400 tons of wrought iron annually. The produce of the forests is one of the chief articles of export. The capital is Bar-le-Duc. The department sends two deputies to the legislature.

MEW, Sea Mew, or Sea Mall. See *Larus*, Ornithology, *Index*.

MEWING, the falling off or the change of hair, feathers, skin, horns, or other parts of animals. This happens in some annually, in others only at certain stages of their lives; but the generality of animals mew in the spring. An old hart casts his horns sooner than a young one. This commonly takes place in the months of February and March, after which they begin to button in March or April; and as the sun grows strong, and the season of the year puts forth the fruits of the earth, so their antlers grow, and are summed full by the middle of June. It is to be observed, that if a hart be gelded before he has antlers, he will never have any; and if he be gelded after he has antlers, he will never cast his horns; again, if he be gelded when he has a velvet head, it will always remain so, without fraying or burnishing.

MEXICO.

History. 667-1051.

I. HISTORY OF MEXICO FROM THE EARLIEST ACCOUNTS TILL ITS SUBJECTION TO SPAIN.

Mexico is situated between the 14th and 21st degrees of north latitude, and between the 91st and 103rd degrees of west longitude; being nearly two thousand miles in length, and in some places six hundred miles in breadth.

Toltecans the first inhabitants.

The Toltecans are the most ancient Mexican nation of which we know any thing. They were expelled from their own country, which is supposed to have been *Tollan* to the northward of Mexico, in the year 472, and for some time they led a wandering life. In whatever place they determined to reside for any considerable time, they erected houses and cultivated the ground. Thus their migrations were extremely slow, and it was not until a hundred and four years after they had set out that they reached a place about fifty miles to the eastward of the city of Mexico, where they settled for twenty years, giving to their new residence the name of *Tollantzinco*. From thence they proceeded about forty miles farther to the west, where they built a city called, from the name of their country, *Tollan*, or *Tula*.

After the final settlement of the Toltecans, the government was changed into a monarchy. Their first king began his reign in 667, and their monarchy lasted 384 years, during which time they reckon only eight princes. We are not, however, to imagine that each of their kings lived long enough to make up this period. It was a custom amongst them that the name of the king should be continued for fifty-two years, and no longer, from the time when he ascended the throne. If he died within that period, the government was carried on in his name by a regency; and if he survived, he was obliged to resign his authority. During the four centuries that the Toltecan monarchy continued, they increased very considerably in number, and built many cities; but when in the height of prosperity, almost the whole nation was destroyed by a famine occasioned by drought, and a pestilence, probably the consequence of the famine. According to Torquemada, at a certain festival-ball given by the Toltecans, the sad-looking devil appeared to them of a gigantic size, with immense arms, and in the midst of the entertainment he embraced and suffocated them; then he appeared in the form of a child with a putrid head, and brought the plague; and, finally, at the persuasion of the same devil, they abandoned the country of Tula.

Succeeded by the Chichemecas.

They were succeeded by the Chichemecas, a much more barbarous people, who came from an unknown country called *Amaquemecan*, where they had for a long time resided, but of it no traces of remembrance can be found amongst any of the American nations known to Europeans; so that Clavigero supposes it must have been situated far to the northward. The motive of the Chichemecas for leaving their own country is not known. They were eighteen months on their journey, and took possession of the desolate country of the Toltecans about an hundred years after the former had left it. They were much more uncivilized than the Toltecans; but they had a regular form of monarchical government, and in other respects were less disgusting in their manners than some of the neighbouring nations. The last king who reigned in Amaquemecan before the departure of the Chichemecas, had left his dominions between his two sons Auchcauhtli and Xolotl, and the latter conducted the new colony. Having proceeded from the ruins of Tula towards Chempoalla and Tepepolio, Xolotl sent his son to survey the country. The prince crossed the borders of the lakes and the mountains which surround the valley of Mexico; then ascending to the top of a very high one, he viewed the whole country, and took possession of it in the name of his father, by shooting four arrows to the four winds. Xolotl being informed by his son of the nature of the country, chose for the capital of his kingdom Tenayuca, about six miles to the northward of the city of Mexico, and distributed his people in the neighbouring territory; but as most of them went to the northward, that part obtained the name of the country of the Chichemecas, in contradistinction to the rest. Here a review of the people was taken, and their number, according to Torquemada, amounted to more than a million.

History. 667-1051.

His people civilized by the Toltecans.

Xolotl finding himself peacefully settled in his new dominion, sent one of his officers to explore the sources of some of the rivers of the country. Whilst performing this task he came to the habitations of some Toltecans, who it seems had still kept together, and were likely once more to become a nation. As these people were not inclined to war, and greatly esteemed for their knowledge and skill in the arts, the Chichemecas entered into a strict alliance with them, and Prince Nopaltzin, who had first surveyed the country, married a Toltecan princess. The consequence of this alliance was the introduction of the arts and knowledge of the Toltecans amongst the Chichemecas. Until now the latter had subsisted entirely by hunting, and such fruits and roots as the earth spontaneously produced. They were clad in the skins of wild beasts, and, like these beasts, they are said to have sucked the blood of the animals they caught; but after their connection with the Toltecans, they began to sow corn, to learn the art of digging and working metals, to cut stones, manufacture cotton, and, in every respect, to make great improvements.

New inhabitants.

When Xolotl had reigned about eight years in his new territories, an embassy of six persons arrived from a distant country not far from Amaquemecan, expressing a desire of coming with their people to reside in the country of the Chichemecas. The king gave them a very gracious reception, and assigned them a district; and, in a few years afterwards, three other princes, with a great army of Acolhuans, who were likewise neighbours of Amequemecan, made their appearance. The king was at that time at Tezcuco, to which place he had removed his court; and here he was accosted by the princes, who, in a submissive and flattering manner, requested him to allow them a place in his happy country, where the people enjoyed such an excellent government. Xolotl not only gave them a favourable reception, but offered them his two daughters in marriage; expressing his concern at having no more, that none might have been excluded from the royal alliance. Upon the third prince, however, he bestowed a noble virgin of Chalco, in whom the Toltecan and Chichemecan blood were united. As the Acolhuans were the more civilized nation of the two, the name of Chichemecas began to be appropriated to the more rude and barbarous portion, who preferred hunting to agriculture, or chose a life of savage liberty in the mountains rather than submit to the restraints of social laws. These barbarians associated with the Otomies, another savage nation who lived to the northward, occupying a tract of more than three hundred miles in extent; and by their descendants the Spaniards were harassed for many years after the conquest of Mexico.

Dominions of Xolotl divided.

As soon as the nuptial rejoicings were over, Xolotl divided his territories into three parts, assigning one to each

History. 1160. of the princes. Acolhuatzin, who had married his eldest daughter, had Azcopazalco, eighteen miles to the westward of Tezcuco; Chiconquauhtli, who had married the other, received a territory named Xaltocan; and Tzontecomatl, who married the lady of inferior rank, obtained one named Coatlichan. The country continued for some time to flourish, population increased greatly, and with it the civilization of the people; but as these advanced, the vices of luxury and ambition increased in proportion. Xolotl found himself obliged to treat his subjects with more severity than formerly, and even to put some of them to death. This produced a conspiracy against him, which, however, he had the good fortune to escape; but whilst he meditated a severe revenge against the conspirators, he was seized with the distemper of which he died, in the fortieth year of his reign, and at a very advanced age.

Nopaltzin the second king. Xolotl was succeeded by his son Nopaltzin, who at the time of his accession, is supposed to have been about sixty years of age. In his time the tranquillity of the kingdom, which had begun to suffer disturbance under his father, experienced much more violent shocks, and civil wars took place. Acolhuatzin, the only one of the three princes who remained alive, thinking the territory he possessed too narrow, made war upon the lord of a neighbouring province named Tapotzotlan, and deprived him of his territory. Huetzin, son to the late prince Tzontecomatl, lord of Coatlichan, fell in love with the grand-daughter of the queen, a celebrated beauty, but was rivalled by a neighbouring lord, who determined to support his pretensions by force of arms. Huetzin, however, defeated and killed his adversary, and then possessed himself of the lady and his estate. This was followed by a rebellion of the whole province of Tollantzinco, so that the king himself was obliged to take the field. As the rebels were very numerous, the royal army was at first defeated, but having at length received a strong reinforcement, the insurgents were overcome, and their ringleaders severely punished. The king did not long survive the restoration of tranquillity to his dominions. He died in the thirty-second year of his reign, and ninety-second of his age, leaving the throne to his eldest son Tlotzin, who was an excellent prince, and reigned thirty-six years.

Quinatzin. Disturbances in various parts. Quinatzin, the son and successor of Tlotzin, proved a vain and luxurious prince. His accession to the throne was celebrated with much greater pomp than any of his predecessors. Xolotl had removed his court from Tenayuca to Tezcuco; but being disgusted with this last place, on account of the conspiracy formed against him there, he had returned to Tenayuca, where the court continued till the reign of Quinatzin, who removed it back to Tezcuco. The reign of Quinatzin, though tranquil at first, was soon disturbed by dangerous revolts and rebellions. These first broke out in two states, named Maztillen and Totopec, situated amongst the northern mountains. The king, having collected a great army, marched without delay against the rebels, and challenged their leaders to come down and fight him upon the plain. This challenge being accepted, a furious engagement ensued, in which, though great numbers fell on both sides, no decisive advantage was gained by either. Frequent engagements took place for the space of forty days, until at last the rebels perceiving that their numbers were daily diminishing, without any possibility of their being recruited like the royal army, surrendered to the king, who punished the ringleaders with great severity. Tranquillity, however, was not yet restored; the rebellion spread to such a degree, that the king was obliged not only to take the field in person, but to employ six other armies, under the command of faithful and experienced generals, in order to reduce the rebels. These proved so successful in their enterprises, that in a short time the rebellious cities were reduced to obedience, and the kingdom enjoyed the blessings of peace during the long reign of Quinatzin, who is said to have sat upon the throne for no less than sixty years. He was succeeded by his son Techotlatla; but as the affairs of the Acolhuans had now begun to be connected with those of the Mexicans, it will be proper to give some account of that people. History. 1216.

Migrations of the Mexicans. The Mexicans, called also the Aztecas, dwelt till the year 1160 in a country called *Aztlan*, situated to the north of the Gulf of California, as appears by the route they pursued in their journey; but how far to the northward we are not certainly informed. Betancourt makes it no less than 2700 miles, and Boturini says it was a province of Asia. The following is stated to have been the cause of their migration. Amongst the Aztecas was a person of great authority named Huiztilin, to whose opinion every one paid the utmost deference. He had conceived a design to persuade his countrymen to change their residence; and in order to effect this he fell upon a stratagem. Having heard, whilst meditating on his scheme, a little bird singing on the branches of a tree, the notes of which resembled the word *tihui*, which in the Azteca language signified "let us go," he took that opportunity to work upon the superstitious credulity of the people. With this view, he took along with him a respectable person, and made him attend to the note of the bird. "What can it mean," says he, "but that we must leave this country, and find ourselves another? Without doubt it is the warning of some secret divinity, who watches over our welfare; let us obey, therefore, his voice, and not draw his anger upon us by a refusal." Tecpaltzin, for that was the name of his friend, readily agreed to the interpretation; and both of them being persons of influence, their united persuasions soon gained over to their project the bulk of the nation, and they accordingly set out.

Separation of the tribes. The Aztecas, when they left their original habitations, were divided into six tribes, but at Culiacan the Mexicans were left with their god (a wooden image), by five of them, viz., the Xochimilcas, Tepanecas, Chalcese, Tlahuicas, and Tlascalans. The cause of this separation is not known, but it was probably occasioned by some disagreement amongst themselves; for the remaining tribe was divided into two violent factions, which persecuted one another; neither did they afterwards construct any more edifices. However, they always travelled together, in order to enjoy the company of their imaginary god. At every place where they stopped an altar was erected to him; and at their departure they left behind them all their sick, and probably also such as were not willing to endure the fatigue of further journeys. They stopped in Tula nine years, and eleven more in the neighbouring parts. At last, in 1216, they arrived at Zumpanco, a considerable city in the valley of Mexico, where they were received in a hospitable manner by the lord of the district. He not only assigned them proper habitations, but became much attached to them, and even demanded from amongst them a wife for his son Ilhuicatl. This request was complied with, and from this marriage all the Mexican kings descended.

Persecution of the Mexicans. The Mexicans continued to migrate from one place to another along the lake of Tezcuco. Xolotl, who was then on the throne of the Acolhuans or Chichemecas, allowed them to settle in whatsoever places of his dominions they thought proper; but some of them finding themselves harassed by a neighbouring lord, were obliged, in the year 1245, to retire to Chapoltepec, a mountain on the western borders of the lake, scarcely two miles distant from the site of Mexico. This took place in the reign of Nopaltzin, when disturbances began to take place in the Acolhuan dominions. The Mexicans, however, did not find themselves any more secure in their new place of residence than formerly. They were persecuted by the neighbouring lords, and obliged to take refuge in a number of small islands, named Acocolco, at the southern extremity of the lake of Mexico. Here for fifty-two years they lived in the most miserable manner,

History. 1314-25.

subsisting on fish, insects, roots, &c., and clothing themselves with the leaves of the amoxtli, which abounds in that lake. In this miserable plight the Mexicans continued till the year 1314, when they were reduced to a state of the most absolute slavery. This was effected by the king of a petty state named Colhuacan. After some years a war broke out between the Colhuans and Xochimilcas, in which the latter gained such advantages, that the former were obliged to employ their slaves to assist them. They accordingly ordered them to prepare for war, but without furnishing them with arms necessary for a military enterprise. The Mexicans were therefore obliged to content themselves with long staves, having their points hardened in the fire; and they also made knives of the stone itztli, and shields of reeds woven together. They agreed not to waste their time in making prisoners, but to content themselves with cutting off one ear of their enemies, and then leaving them without further injury. They adhered punctually to this resolution, and rushing furiously upon the Xochimilcas, cut off an ear from as many as they could, killing those who resisted the performance of this auricular excision. In short, so well did the Mexicans acquit themselves in this engagement, that the Xochimilcas fled, and took refuge amongst the mountains. After the battle the Colhuan soldiers presented themselves before their general with the prisoners they had taken, by the number of which alone they judged of their valour. The Mexicans had taken only four, and these they kept concealed for the purpose of sacrificing them. The Colhuans, therefore, seeing no trophies of their valour, began to reproach them with cowardice; but the Mexicans, producing their baskets of ears, desired them to judge from these how many prisoners they might have taken, had they not been unwilling to retard their victory by taking up time in binding them.

The first human sacrifice in Mexico.

Notwithstanding the valour displayed by the Mexicans in this engagement, it does not appear that their haughty masters were in the least inclined to afford them easier terms than before. Having erected an altar to their god, they demanded of their lord something precious to offer in sacrifice to him; but he in disdain sent them a dirty cloth, enclosing the filthy carcase of a vile bird. This was carried by Colhuan priests, and without any ceremony laid upon the altar. The Mexicans, with apparent unconcern, removed this filthy offering, and put in its place a knife made of itztli, and an odoriferous herb. On the day of the consecration, the Colhuan prince attended with his nobility; not with a view to do honour to the festival, but to make a mockery of the Mexicans. Their derision, however, was soon changed into horror, when the Mexicans, after a solemn dance, brought forth the four Xochimilcan prisoners they had taken; and, after having made them dance a little, cut open their breasts with the knife which lay upon the altar, and plucking out their hearts, offered them, whilst yet palpitating with life, to their sanguinary idol. This had such an effect upon the spectators, that both the king and his subjects desired the Mexicans immediately to quit their territories and go where they pleased. This order was instantly obeyed. The whole nation took their route towards the north, until they came to a place named *Acatzitzintlan*, situated between two lakes, and afterwards named *Mexicaltzinco*; but being discontented with this situation, they proceeded to *Iztacalco*, still nearer to the site of Mexico. Here they formed the image of a little mountain of paper, and danced round it a whole night, singing their victory over the Xochimilcas, and reuniting thanks to their god for having freed them from the yoke of the Colhuans. Clavigero is of opinion, that by this mountain they represented Colhuacan, as in their pictures it was always represented by a hunch-backed mountain; and this is the literal signification of the name.

City of Mexico founded.

The city of Mexico was founded in the year 1325, in the most incommodious situation we can imagine, namely, on a small island named Tenochtitlan, in the middle of a great lake, without ground to cultivate for subsistence, or even room sufficient to build habitations. The life of the people, therefore, was for some time as miserable here as it had been when they were on the islands at the end of the lake, and they were reduced to the same shifts to maintain themselves. To enlarge the boundaries of their island, they drove palisades into those parts of the water which were most shallow, terracing them with stones and turf, and uniting to their principal island several other smaller ones which lay in the neighbourhood. In order to procure for themselves stones, wood, and other materials for constructing their habitations, as well as clothing and other necessaries, they instituted a commerce with the people who dwelt upon the borders of the lake, supplying them with fish, waterfowl, and other articles; and in return for all this they received the necessaries above mentioned. The greatest effort of their industry, however, was the construction of floating gardens, by means of bushes and of the mud of the lake; and these they brought to so much perfection that they produced maize, pepper, chia, French beans, and gourds. For thirteen years that the Mexicans had to struggle with extreme difficulty, they remained at peace; but no sooner did they begin to prosper and live comfortably, than the inveterate enmity between the two factions broke out in all its fury. This produced a separation; and one of the parties took up their residence on a small island at a little distance to the northward, which, from a heap of sand found there, they at first named *Xaltilolco*, but afterwards *Tlatelolco*, from a terrace constructed by themselves. This island was afterwards united to that of Tenochtitlan.

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Barbarity of their religion.

About this time the Mexicans divided their city into four parts, each quarter having now its tutelar saint, as it had formerly had its tutelar god. In the midst of their city was the sanctuary of their great god *Mexitli*, whom they constantly preferred to all the rest. To him they daily performed acts of adoration; but instead of making any progress in humanity, they seem to have daily improved in the most horrible barbarities, at least in their religion. The dreadful sacrifices made of their prisoners, could only be exceeded by that which we are about to relate. Being now on a more respectable footing than formerly, they sent an embassy to the petty king of Colhuacan, requesting him to send them one of his daughters, in order that she might be consecrated the mother of their protecting god. The unsuspecting prince readily complied with their desire, and the unfortunate princess was conducted in great triumph to Mexico; but no sooner had she arrived than she was sacrificed in a shocking manner; and, to add to the horror of the deed, the body was flayed, and one of the bravest young men of the nation dressed in her skin. Her father, ignorant of this dreadful transaction, was invited by the Mexicans to be present at the apotheosis of his daughter, and went to see the solemnity, and to worship the new divinity. He was led into the sanctuary, where the young man stood clothed in the bloody skin of his daughter; but the darkness of the place prevented him from seeing what was before him. They gave him a censer in his hand, and some copal to begin his worship; but having discovered by the flame of the copal the horrible spectacle, he ran out in a distracted manner, calling in vain upon his people to revenge the injury.

Acamapitzin the first king of Mexico.

In the year 1352, the Mexican government was changed from an aristocracy to a monarchy. At first the people were governed by twenty lords, of whom one had an authority superior to the rest. This naturally suggested the idea of monarchy; and to this change they were also induced by the contemptible state in which their nation still continued, thinking that the royal dignity would confer upon it a degree of splendour which otherwise it could not enjoy, and that by having one leader, they would be better able to oppose their enemies. Proceeding, therefore, to elect a king, the choice fell upon Acamapitzin, a man held in great

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estimation amongst them, and descended from Opochtli, a noble Aztecan, and a princess of the royal family of Colhuacan. As he was yet a bachelor, they attempted to negociate a marriage, first with the daughter of the lord of Tacuba, and then of the king of Azcapozalco; but these proposals being rejected with disdain, they applied to Acolmiztli lord of Coatlichan, and a descendant of one of the three Acolhuan princes, who complied with their request, and the nuptials were celebrated with great rejoicings.

The Tlatelolcos.

In the mean time, the Tlatelolcos, the natural rivals of the Mexicans, resolved not to be behind them in any thing which had the least appearance of augmenting the glory of their state. They likewise, therefore, chose a king; but not thinking proper to choose him from amongst themselves, they applied to the king of the Tepanecos, who readily sent them his son; and he was crowned first king of Tlatelolco in 1353. In this the Tlatelolcos seem to have had a design of humbling their rivals, as well as of rendering themselves more respectable; and therefore it is very probable that they had represented the Mexicans as wanting in that respect due to the Tepanecan monarch, from having elected a king without his leave, though at the same time they were tributaries to him. The consequence of this was, that he resolved to double their tribute. Hitherto they had paid only a certain number of fish and water-fowl; but now they were ordered to bring in also several thousands of fir and willow plants to be set in the roads and gardens of Azcapozalco, and to transport to the court a great floating garden, which produced vegetables of every kind known in Anahuac. This being accomplished with great difficulty, the king commanded them next year to bring him another garden, with a duck and a swan in it both sitting upon eggs, but so, that on their arrival at Azcapozalco the brood might be ready to hatch. This was also done, and the prince had the opportunity of observing the young birds come out of the eggs. The third year they were ordered to bring a live stag along with a garden. This was more difficult than any of the former tasks, because they were obliged, in order to hunt the stag, to go to the mountains of the continent, where they were in danger of falling into the hands of their enemies; however, this also was accomplished, and the desire of the king gratified. In this manner the Mexicans were oppressed for no less than fifty years. They freed themselves, however, from all their difficulties by vigorous exertions, absurdly ascribing to the protection of that malevolent being whom they worshipped, all the glory of every deliverance. Acamapitzin governed this city, which at that time comprehended the whole of his dominions, for thirty-seven years in peace. He is said also to have conquered four considerable cities; but Clavigero thinks he must in this have been only an auxiliary.

Huitzilihuitl the second king.

Acamapitzin died in the year 1389, lamented by the Mexicans, and his death was followed by an interregnum of four months. As the deceased monarch had formerly resigned his authority into the hands of his nobles, it was necessary that a new election should take place; and when this was done, the choice fell upon Huitzilihuitl, the son of Acamapitzin. As he was still unmarried, it was resolved, if possible, to procure for him an honourable and advantageous match. With this view, a deputation of nobility was sent to the king of Azcapozalco, requesting, in humble terms, an alliance with one of his daughters. The expressions made use of by these ambassadors are said to have been particularly elegant in the Mexican language. "We beseech you," said they, "with the most profound respect, to take compassion on our master and your servant Huitzilihuitl, confined amongst the thick rushes of the lake. He is without a wife, and we without a queen. Vouchsafe, sir, to part with one of your jewels or most precious feathers. Give us one of your daughters, who may come to reign over us in a country which belongs to you." This oration had such an effect upon the king, that he granted their request, and a Tepanecan princess was conducted in great triumph to Mexico, where the marriage was solemnized with the utmost joy. Though this princess brought him a son the first year of their marriage, the king, in order to strengthen himself by fresh alliances, married also the daughter of another prince, by whom he had Montezuma Ilhuicamina, the most celebrated of all the Mexican kings.

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Inhabitants of Tlatelolco.

As the Mexicans advanced in wealth and power, so did their rivals the inhabitants of Tlatelolco. Their first king died in 1399, leaving his subjects greatly improved in civilization, and the city much enlarged and beautified. The rivalship which subsisted between the two cities had indeed greatly contributed to the aggrandizement of both. The Mexicans had formed so many alliances by marriage with the neighbouring nations, had so much improved their agriculture and floating gardens on the lake, and had built so many more vessels to supply their extended commerce and fishing, that they were enabled to celebrate their secular year, answering to the year 1402 of our era, with far greater magnificence than they had ever done since they left their original country of Atztlan.

Unfortunate reign of Techotlala's son.

During all this time Techotlala, the son of Quinatzin, continued to reign in Acolhuacan, and for thirty years enjoyed uninterrupted tranquillity; but being now far advanced in years, and finding his end approaching, he called to him his son Ixtlilxochitl, and recommended to him to beware of the ambitious disposition of the king of Azcapozalco, as he was apprehensive that he might attempt something against the peace of the empire. His suspicions were verified; for on the death of Techotlala, which happened in 1406, the king of Azcapozalco, without making the usual submissions to the new king, to whom he was a feudatory, set out for his own territories, with a view to excite other feudatory princes to rebellion. Having called to him the kings of Mexico and Tlatelolco, he told them, that Techotlala, who had long tyrannized over that country, being dead, he designed to procure freedom to the princes, so that each might rule his own territory entirely independent of the king of Acolhuacan; but for this purpose he required their assistance, and trusted to their well-known spirit to take part with him in the proposed enterprise. He likewise informed them that in order to ensure success, he would find means to unite other princes in the confederacy. In the mean time the new king of Acolhuacan was employed in settling the affairs of his kingdom, and endeavouring to gain the good will of his subjects. The combination against him was soon discovered; but though Ixtlilxochitl was desirous of heading his army in person, he was dissuaded from so doing by his courtiers; so that the conduct of the war was committed to his generals. To weaken the enemy, they ravaged the territories of six revolted states; but, notwithstanding this, and the superior discipline of the royal army, the war was carried on by the rebels with great obstinacy, their armies being constantly recruited by fresh troops in proportion to their losses. At last, after a ruinous contest of three years, the king of Azcapozalco, finding that his resources would at last fail him, sued for peace; but with a design of accomplishing by treachery what he had not yet been able to effect by force. His adversary, equally reduced with himself, consented to a peace, although he knew that the Tepanecan prince intended to observe it no longer than suited his purpose.

Chimalpopoca third king of Mexico.

In the year 1409 died Huitzilihuitl king of Mexico, who left the right of electing a successor to the nobility. They made choice of his brother Chimalpopoca; and hence it became an established law to choose one of the brothers of the deceased king, or, if he had no brothers, to elect one of his grandsons. Whilst the new prince was endeavouring to secure himself on the throne, the treacherous Tezozomoc employed all the means in his power to strengthen the party he had formed against the king of Acolhuacan. In

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this he had such success, that the unfortunate prince found himself reduced to the necessity of wandering amongst the neighbouring mountains, at the head of a small army, accompanied by the lords of Huexotla and Coatlichan, who remained faithful to him. The Tepanecans by intercepting his provisions, distressed him to such a degree, that he was forced to beg them of his enemies. One of his grandsons was sent to Otompan, a rebel state, to request them to supply their king with the provisions which he stood in need of, and to exhort them to abandon the cause of the rebels, which they had espoused. No task could be more dangerous; yet such was the magnanimity of the young prince's disposition, that he readily set out on the journey, nor was he deterred by the information he received that there were in the place certain Tepanecans who had come on purpose to publish a proclamation from Tezozomac. He went boldly to the most public place of the town, and in presence of those who published the proclamation made known his request. But this heroism did not meet with the success it deserved. His propositions were derided; yet the people did not offer any further insult, until one of the meaner sort threw a stone at him, exciting others of the same stamp to put him to death. The Tepanecans, who had hitherto remained silent, now perceiving their opportunity, joined in the general cry to kill the prince, and began also to throw stones. The prince attempted first to defend himself, and afterwards to escape by flight; but, both being equally impossible, he fell under a shower of stones. The Tepanecans, exulted in this act of treachery, and soon afterwards cut off Ixtlilxochitl himself, after having treacherously persuaded him to hold a conference with two of their captains. This perfidious act was committed in sight of the royal army, who were too weak to revenge it. The royal corpse was saved with difficulty; and Nezahualcojotl, the heir-apparent to the crown, was obliged to shelter himself amongst the bushes from the fury of his enemies.

Acolhuacan conquered by Tezozomoc

Tezozomoc having now in a great measure gained his point, proceeded to pour down his troops upon those cities and districts which had remained faithful to the late unfortunate monarch. The people made a desperate defence, and killed great numbers of their enemies; but at last being reduced by the calamities of war, and in danger of total extermination, they were obliged to quit their habitations and flee to other countries. The tyrant, finding himself superior to all his adversaries, then gave Tezcuco to Chimilpopoca king of Mexico, and Huexotla to Tlacacotl king of Tlatelolco; at the same time placing faithful governors in other places, and appointing Azcapozalco, the capital of his own territory, the royal residence and capital of Acolhuacan. Prince Nezahualcojotl was present in disguise at this disposal of his dominions, along with several other persons of distinction, who were enemies of the tyrant; and so much was he transported with passion, that with difficulty could he be restrained from killing Tezozomoc on the spot, though this would certainly have been done at the expense of his own life. All the rest of the Acolhuacan empire submitted; and Nezahualcojotl saw himself for the present deprived of all hopes of obtaining the crown. Tezozomoc had now attained the summit of his ambition. But instead of conciliating the minds of his new subjects, he oppressed them with fresh taxes; and being conscious of the precarious situation in which he stood, and tormented with remorse on account of his crimes, he fell into melancholy, and was constantly haunted with frightful dreams. At length he expired in the year 1422, leaving the crown to his son Tajatzin.

The throne usurped by Maxtlaton.

Tezozomoc was no sooner dead than Maxtlaton, without paying the least regard to his father's will, began to exercise the functions of sovereign. Although it was the right of Tajatzin to invite to his father's funeral whomsoever he pleased, Maxtlaton took that upon himself. Nezahualcojotl, though not invited, came amongst the rest; but though Teuctzintli, brother to Maxtlaton, insisted upon his being put to death, the latter opposed it, since it could not then be done privately, and he hoped to find another opportunity. But no sooner were the funeral ceremonies terminated, than Maxtlaton behaved in such a manner to his brother Tajatzin, that the prince thought proper to retire to Chimilpopoca king of Mexico, to whom he had been particularly recommended by his father, in order to obtain his advice. This monarch, agreeably to the character of that age and people, advised him to invite his brother to an entertainment, and then to murder him. Unluckily for both, this discourse was overheard by a servant, who, in expectation of a reward, informed the tyrant of what he had heard; but Maxtlaton, pretending to disbelieve his story, drove the informer from his presence with ignominy. Notwithstanding this pretence, however, the tyrant had not the least doubt of the truth of what was told him, and therefore determined to rid himself of his brother without delay. This he soon accomplished in the very same way that had been projected against himself. Tajatzin, along with the kings of Mexico, Tlatelolco, and several other feudatory princes, were invited by Maxtlaton to an entertainment. The king of Mexico prudently excused himself, but the unsuspecting Tajatzin fell into the snare. He came to the place of entertainment, and was instantly put to death. The company were greatly alarmed; but Maxtlaton, having explained to them his reasons for so doing, they not only excused him, but proclaimed him king, being in this no doubt much more influenced by fear than by affection.

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Fate of the king of Mexico.

Although the king of Mexico escaped a sudden death by his absence at this time, yet it was only to perish in a manner more slow and ignominious. The vengeance of Maxtlaton first appeared by sending him a woman's dress in return for the present the king sent him as a feudatory; which being a reflection on his courage, was, therefore, the highest affront that could be offered him. This insult, however, was quickly followed by one of a more aggravated description. Having heard that one of the Mexican prince's wives was of extraordinary beauty, he enjoined some Tepanecan ladies who were accustomed to visit that princess, to invite her to spend some days with them at Azcapozalco. This being complied with, the tyrant easily obtained an opportunity of ravishing her, and then sent her back to her husband. Chimilpopoca was so much affected by this misfortune, that he resolved to offer himself up as a sacrifice to his god. Maxtlaton, however, had resolved that he should not have even that satisfaction. Hence at the time of the ceremony, he sent a body of troops, who entering Mexico without resistance, carried off the king alive, to the astonishment of the multitude, who confounded by this unexpected adventure, did not attempt to offer any resistance. Chimilpopoca having been carried prisoner to Azcapozalco, was confined in a strong wooden cage, the common prison for criminals. But Maxtlaton was still unsatisfied. He wished to get into his hands Nezahualcojotl, and with this view sent a message to him, pretending that he was willing to come to an agreement respecting the kingdom of Acolhuacan. Although the prince was well assured of the tyrant's treacherous intention, he went boldly to his palace, presented himself before him, and told him that he had heard of the imprisonment of the king of Mexico; he had also heard that he wished to take away his own life; and he desired him to do so, and thus gratify his malice. Maxtlaton was so struck with this speech, that he assured the prince he had not formed any design against his life, and that he neither had put to death the king of Mexico, nor would attempt to do so. He then gave orders for his being properly entertained, and even allowed him to pay a visit to the king of Mexico in prison. The unfortunate Chimilpopoca, after reciting his misfortunes, requested the prince not to return to court, where they would certainly fall upon some project for taking away his life; and

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having pathetically recommended to him the care of his subjects, made him a present of a gold pendant and some other jewels which he wore.

Itzcoatl raised to the throne of Mexico.

In the mean time, the Mexicans raised to the throne Izcoatl, the son of Acamapitzin by a slave, and who was accounted the justest, bravest, and most prudent of all the Mexican nation. His election was no less pleasing to Nezahualcojotl and his party, than it was offensive to Maxtlaton. An alliance was quickly concluded between the exiled prince and the king of Mexico; and this was soon followed by the commencement of hostilities on the part of the former. His first enterprise was directed against the city of Tezcuco, which he determined to take by assault, but this was prevented by the submission of the inhabitants. He however put to death all the officers established by the tyrant, and all the Tepanecans he found there. The same day another large city named Acolman was furiously attacked by a detachment of his army, and great numbers put to the sword, amongst which were the governor, who was brother to Maxtlaton.

Embassy undertaken by Montezuma.

The Mexican monarch, hearing of the successes of his ally, sent an embassy to congratulate him thereupon. His ambassador was a son of king Huitzilihuitl, named Montezuma, who for his invincible courage and great qualities was surnamed the "man of great heart and the archer of heaven." The journey was extremely dangerous; but Montezuma undertook it without any fear, accompanied by another nobleman. They got in safety to the place where the prince was, but had the misfortune to be taken prisoners, and carried to Chalco, the lord of which city, named Toteotzin, was a most inveterate enemy of the Mexicans. By him he was immediately put in close confinement, under the care of one Quateozin, who was inviolably attached to the Mexican interest. Orders were also given to the latter to provide no sustenance for the prisoners but what was prescribed by his lord, until the mode of death which they were to suffer should be determined on. Toteotzin then sent his prisoners to them, that they might be sacrificed there if they thought proper. These people, however, rejected the proposal with disdain; upon which Toteotzin, thinking to regain the favour of Maxtlaton, informed him of the prisoners he had in his possession. But Maxtlaton called him a double-minded traitor, and commanded him instantly to set the prisoners at liberty. Before this answer arrived, however, Quateozin had instructed the prisoners how to make their escape, and directed them also not to return by land lest they should again be intercepted, but to embark at a certain place, and proceed by water to Mexico. They followed his advice exactly; and having reached the place to which they were directed, arrived safely at their city, to the great surprise and joy of the inhabitants.

Maxtlaton declares war against Mexico.

Toteotzin, being enraged at the loss of his prisoners, put Quateozin to death, and destroyed all his family excepting one son and a daughter; the latter of whom fled to Mexico. Maxtlaton, too, notwithstanding his generosity to the prisoners, prepared to wage war with the Mexicans who had agreed to unite their troops with those of the prince. The Mexican populace, terrified at engaging so powerful an enemy, demanded that their king should submit and sue for a peace. The king was obliged to consent; and it required the utmost exertions of Montezuma's eloquence to persuade the people to agree to a commencement of hostilities. This being settled, the king next called together the chief nobility, and asked which of them would have the courage to carry an embassy to the king of the Tepanecans. The adventure appeared so hazardous, that all of them maintained a profound silence, until Montezuma declared himself willing to undertake the arduous enterprise. He was ordered to propose peace to Maxtlaton, but to accept of no dishonourable conditions; and to this he punctually adhered. Maxtlaton refused any immediate answer, but promised to give one next day, after he had consulted his nobility. Montezuma, dreading some treachery if he staid all night, promised to return next day, which he did, and was told that Maxtlaton had determined upon war. Montezuma then performed the ceremony of challenging him by presenting him, with certain defensive weapons, anointing his head, and fixing feathers upon it, as was customary in such cases. Lastly, he protested, in the name of his master, that as Maxtlaton would not accept of the offered peace, he and all the Tepanecans would infallibly be ruined. Maxtlaton evinced not the least sign of displeasure, but in like manner gave Montezuma arms to present to the king of Mexico, and directed him, for his own personal security, to return in disguise through a small outlet from the palace. Montezuma followed his advice, but as soon as he found himself out of danger, he began to insult the Tepanecan guards; and although they rushed violently upon him, he not only escaped from their attack, but killed one or two of them. Upon his return to Mexico, the populace were again thrown into the utmost consternation by the news that war was inevitable; and they now requested the king to allow them to retire from their city, of which they supposed the ruin to be certain. The king encouraged them with the hopes of victory. "But if we are conquered," replied they, "what will become of us?" "If that happen," answered the king, "we are that moment bound to deliver ourselves into your hands, to be made sacrifices at your pleasure."

He is defeated and killed.

Matters being thus settled, intelligence was sent to prince Nezahualcojotl to repair with his army to Mexico, which he did without delay; and the day after his arrival a furious engagement took place. The Tepanecan army was commanded by a general named Mazatl, Maxtlaton himself not judging it proper to quit his capital. The soldiers on both sides fought with the utmost bravery; but towards night the Mexicans, being disheartened by seeing the army of their enemies continually increasing in number, began once more to lose their courage and talk of surrendering. The king, greatly concerned, asked Montezuma what should be done to dissipate the fears of the people? That brave prince replied, that they must fight till death; that if they died with arms in their hands, it would be honourable; but that to survive their defeat, would be eternal ignominy. Nothing could be more salutary than this advice at so critical a juncture. The Mexicans had already begun to implore the mercy of their enemies, and to promise to sacrifice their chiefs, whose ambition had brought the whole nation into such a dilemma. On hearing this, the whole body of nobility, with the king and Montezuma at their head, assaulted the enemy so furiously, that they repulsed them from a ditch of which they had taken possession; after which, Montezuma, happening to encounter Mazatl the Tepanecan general, struck him such a blow on the head that he fell down lifeless. Thus the Mexicans were inspired with fresh courage, and their enemies proportionally dispirited; yet they retired that night to the city, in some hopes of being able to retrieve their fortune next day. Maxtlaton encouraged them by every method in his power; but fortune proved still more unfavourable to his cause than the day before. The Tepanecans were now entirely defeated, and the city of Accapozalco taken. Maxtlaton, who seems not to have had the courage to fight, had not now the presence of mind to flee. He attempted indeed to hide himself; but being quickly discovered, he was beaten to death with sticks and stones. The city was plundered, the inhabitants were butchered, and the houses destroyed by the victors. This victory proved decisive in favour of the confederates. Every other place of strength in the country was quickly reduced, until the Tepanecans, finding themselves upon the verge of destruction, sent an humble embassy to the king of Mexico, requesting to be taken under his protection, and to become tributaries

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to him. Itzcoatl received them graciously, but threatened them with total extirpation if they violated the fidelity they had sworn to him.

Nezahualcojotl made king of Acolhuacan.

After this extraordinary success, Itzcoatl took good care to have the above-mentioned contract ratified between the nobility and common people, by which the latter were bound to perpetual services. Those who had discouraged the soldiers in time of battle were banished forever from the state of Mexico; whilst Montezuma and others who had distinguished themselves by their bravery, were rewarded with lands, as was usual with other conquerors. Itzcoatl, now finding himself firmly seated on the throne of Mexico, set about performing his engagements to the Acolhuacan prince, by seating him upon the throne of his ancestors. Having again effected a junction of their armies, they marched against Huaxtlo, a city which refused to submit, even though terms of pardon were offered to them. Instead of this, they rashly ventured a battle, in which they were entirely defeated; and they were then glad to send a deputation to move the enemy to compassion. At last all obstacles being removed, Nezahualcojotl was seated upon the throne of Acolhuacan; the auxiliary troops were dismissed; and Itzcoatl was left at liberty to pursue his conquests, in which he was still assisted by the king of Acolhuacan. The first expedition was against Cojohuacan, and other two Tepanecan cities, who had not only themselves refused submission, but had excited others to shake off the yoke. The war against them proved bloody. Three battles were fought, in which Itzcoatl gained no other advantage than making the enemy retreat a little; but in the fourth, whilst the two armies were hotly engaged, Montezuma, with a body of chosen troops, which he had placed in ambuscade, attacked the rear-guard of the rebels with such vigour, that they were soon disordered, and obliged to flee to the city. The conquerors pursued them thither; and Montezuma perceiving that they intended to fortify themselves in the great temple, frustrated their design by getting possession of it and burning the turret. By this disaster they were so terrified, that they fled to the mountains south of Cojohuacan; but even there the royal army overtook and pursued them more than thirty miles, till they came to another mountain, where, exhausted with fatigue, and seeing no means of escape, they were obliged to surrender at discretion.

Alliance between the kings of Mexico, Acolhuacan, and Tepaneca.

Having thus accomplished the conquest of Cojohuacan and of the other rebellious cities, the two kings returned to Mexico. Itzcoatl gave great part of the Tepanecan country, with the title of king of Tacuba, to Totoquihuatzin, a grandson of Tezozomoc, but who does not appear to have been in any way concerned in his projects against the Mexicans. An alliance was then formed amongst the three kings. The king of Tacuba held his crown on condition of serving the king of Mexico with all his troops, at any time when required; and for this he was to have a fifth of the spoils taken from the enemy. The king of Acolhuacan was likewise to assist the king of Mexico in war; and for this he was to have one third part of the plunder, after deducting the share of the king of Tacuba, whilst the remainder was to belong to the king of Mexico. The kings of Tacuba and Acolhuacan were both declared honorary electors of the kings of Mexico, the real electors being four nobles; and the king of Mexico was likewise bound to assist in the wars of his allies whenever it was demanded. After having thus settled matters amongst themselves, and rewarded their soldiers, Itzcoatl set out along with Nezahualcojotl for Tezcuco, where the Acolhuacan king was crowned with all possible ceremony. Here the new king took every method which prudence could suggest to establish his authority on a permanent basis; but whilst he was thus employed, the Xochimilcas, fearing lest the Mexicans might conquer their country as they had done that of the Tepanecans, held a council as to what should be done to prevent such a disgrace. In this council it was determined to commence hostilities against that rising state, before it should become more formidable by new conquests. Itzcoatl was no sooner informed of this determination, than he sent Montezuma with a great army against them. The Xochimilcas met him with one still more numerous; but being worse disciplined they were quickly defeated, and their city taken a short time afterwards. This conquest was followed by the reduction of Cuitlahuac, situated on a small island in the lake of Chalco. Their insular situation gave them sufficient confidence to attack the Mexicans. The king was so sensible of the difficulty of this enterprise, that he proposed to attack them with the whole force of the alliance. Montezuma, however, with only a small number of men of his own training, whom he had furnished with proper vessels, reduced them in seven days.

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Itzcoatl died in the year 1436, at a very advanced age, in the height of prosperity, and was succeeded by Montezuma I. the greatest monarch that ever sat on the Mexican throne. Before his coronation, that he might comply with the barbarous rites of his religion, he made war upon the Chalcese, in order to procure the prisoners who were to be sacrificed at his coronation; and scarcely was this ceremony over, when a new war commenced, which terminated in the destruction of that city. This quarrel happened between the Chalcese and the Tezcucans. Two of the royal princes of Tezcuco having gone a-hunting on the mountains which overlook the mountains of Chalco, whilst employed in the chase, and separated from their retinue, with only three Mexican lords, fell in with a troop of Chalcese soldiers, who, to gratify the cruelty of their master, carried them all prisoners to Chalco. The cruel and inconsiderate tyrant who commanded there instantly put them to death; after which he caused their bodies to be salted, dried, and placed in an hall of his palace, where they served as supporters to the pine torches burned there for lights every evening. The king of Tezcuco, being overwhelmed with grief, and to the last degree exasperated at such an inhuman act, called for the assistance of the allied kings. The city was attacked at once by land and water; and the inhabitants, knowing that they had no mercy to expect, fought with the fury of despair. Even the old tyrant who commanded them, though unable to walk, caused himself to be carried in a litter amongst the combatants; notwithstanding which they were totally defeated, and the most unspairing vengeance executed upon them.

Montezuma I. king of Mexico.

Tlatelolco reduced, and Moquihuix made king.

Montezuma, on his return, found himself obliged to encounter an enemy more formidable on account of his vicinity, than enemies more powerful at a distance. This was the king of Tlatelolco, who had formerly conspired against the life of Itzcoatl, and finding himself disappointed in this, had tried to reduce his power by entering into a confederacy with some of the neighbouring lords. At that time his designs proved abortive, but he resumed them in the time of Montezuma; the consequence of which was, that he was defeated and killed. One Moquihuix was chosen in his stead; and in the election of that chief it is probable that Montezuma had a considerable share. This was followed by conquests of a much more important nature. The province of Cuihixcas, situated to the southward, was added to his dominions, comprehending a tract of country more than an hundred and fifty miles in breadth; then, turning to the westward, he conquered another province named Tzompahuacan. This success, however, was for a short time interrupted by a war with Atonaltzin, lord of a territory in the country of the Mixtacas. This prince, being elated on account of the great wealth he possessed, took it into his head that he would allow no Mexican to travel through his country. Montezuma sent ambassadors to know the reason of such strange conduct;

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but Atonaltzin gave them no other answer than shewing them some part of his wealth, making a present to the king, and desiring them to observe how much the subjects of Atonaltzin loved him; adding that he willingly accepted of war, which was to determine whether he should pay tribute to the Mexicans or the Mexicans to him. Montezuma having informed his allies of this insolent answer, sent a considerable army against Atonaltzin, but had the mortification to be informed of its defeat. Montezuma, chagrined at this first check, determined to command his next army in person; but before he could call together another, Atonaltzin had drawn into a confederacy with him the Huexotzincas and Tlascalans, who were glad of the opportunity, as they supposed, of reducing the power of the Mexicans. Their numbers, however, availed them but little; as Montezuma in the first engagement totally defeated the confederate army. The allies of Atonaltzin were particularly unfortunate; for such of them as were not killed in the field of battle, were destroyed by their own party out of revenge for the unfortunate event of the battle.

Mexican dominions changed.

By this victory the Mexican monarch became master not only of the dominions of Atonaltzin, but of those of many other neighbouring princes, against whom he made war on account of their having put to death some Mexican merchants or couriers without any just cause. The conquest of Cuetlachtan or Cotasta, however, which he attempted in 1457, proved a much more difficult task. This province is situated on the coast of the Mexican Gulf, and had formerly been inhabited by the Olmecans, whom the Tlascalans had driven out. The inhabitants were very numerous, but dreading the power of Montezuma, called in those of Tlascala, together with the Huexotzincas, to their assistance. Along with these the allies also induced the Cholulans to join the confederacy, so that this seems to have been the most formidable combination which had yet been formed against the Mexican power. Montezuma collected an excellently equipped army, which, however, he did not on this occasion command in person. It contained a great number of persons of high rank, amongst whom were three princes of royal blood, and Moquihuix, king of Tlatelolco, already mentioned. The combination of the three republics against Mexico was not known at court when the army set out; but Montezuma, being informed of it soon afterwards, sent an order to his generals to return. This accorded so ill with the romantic notions of valour entertained by the Mexicans, that a consultation was held whether they should obey it or not. At last it was determined that the king's order should be obeyed; but no sooner had this been agreed to, than Moquihuix accused them all of cowardice, and threatened, with his own troops, unassisted, to go and conquer the enemy. His speech had such an effect upon them all, that they went to meet the confederates. The Cotastese fought with great valour, but were unable to resist the royal forces; and their allies were almost totally destroyed. Six thousand two hundred of them were taken prisoners, and soon afterwards sacrificed to the Mexican god of war in the barbarous manner already described.

Inundation and famine at Mexico.

During the reign of this great monarch a violent inundation happened in Mexico. The lake, swelled by the excessive rains which fell in the year 1446, poured its waters into the city with such violence, that many houses were destroyed, and the streets inundated to such a degree that boats were everywhere made use of. The inundation was soon followed by a famine. This was occasioned by the stinting of the crop of maize in 1448, the ears whilst young and tender having been destroyed by frost. In 1450 the crop was totally lost for want of water; and in 1451, besides the unfavourable seasons, there was a scarcity of seed. Hence, in 1452, the necessities of the people became so great, that they were actually obliged to sell themselves as slaves, in order to procure subsistence. Montezuma permitted them to go to other countries for support; but being informed that many sold themselves for a few days' provisions, he ordered, by proclamation, that no woman should sell herself for less than four hundred ears of wheat, nor any man for less than five hundred. He opened also the public granaries for the relief of the lower classes; but nothing could arrest the progress of the famine.

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Axayacatl succeeds Montezuma.

Montezuma was succeeded by Axayacatl, who like his predecessor instantly commenced a war, for no other reason than that he might obtain prisoners to sacrifice at his coronation. He pursued Montezuma's plan of conquest, in which, however, he was not very successful; many of the provinces reduced by that monarch having revolted after his death, so that it was necessary to reconquer them. On his returning victorious from one of these expeditions, he built a new temple, to which he gave the name of Coatlon; but the Tlatelolcos, whose ancient rivalship seems to have revived on the death of Montezuma, built another in opposition, which they called Coxolotl. Thus the former hatred between the two nations was renewed, and an enmity arose which ended in the ruin of the Tlatelolcos.

Death of the kings of Acolhuacan and Tacuba.

The Mexicans sustained an irreparable loss in 1469 and 1470 by the death of their allies the kings of Tacuba and Acolhuacan. The king of Tacuba was succeeded by his son Chimilpopoca, and the Acolhuacan monarch by his son Nezahualpilli. A short time after the accession of the latter, the war broke out between the Tlatelolcos and Mexicans, which ended in the destruction of the former. Moquihuix had been married by Montezuma to a sister of Axayacatl, now on the throne of Mexico; but it appears that this princess was never the object of his affection. On the contrary, he took all methods of expressing his dislike, either out of enmity to herself, or from envy of the superior greatness of her brother. Not content with this, he entered into an alliance with a great number of the neighbouring states, in order to reduce the Mexican greatness. His wife, however, being informed of this scheme, communicated the particulars to her brother; and soon afterwards, being impatient of the ill usage she received, came to Mexico with her four sons to claim the protection of her brother. This uncommon accident so greatly exasperated the Mexicans and Tlatelolcos against each other, that wherever they met, they fought, abused, and murdered each other. The king of Tlatelolco prepared for war with many horrid ceremonies, of which the drinking of human blood was one. A day was appointed for attacking Mexico. Xiloman, lord of Colcuacan, was to begin the attack, and then to pretend flight, in order to induce the Mexicans to follow him; after which the Tlatelolcos were to fall upon their rear. For some reasons, however, which are unexplained, the Tlatelolcos commenced the attack without waiting for Xiloman; the consequence of which was, that he retired in disgust, leaving them to finish the battle in the best way they could. The engagement lasted until night, when the Tlatelolcos were obliged to retire. During the night Axayacatl disposed of his troops in all the roads which led to Tlatelolco, appointing them to meet in the market-place. The Tlatelolcos, finding themselves attacked upon all sides, retired gradually before the Mexicans, until at last they were forced into the market-place, where they found themselves worse than ever on account of its narrowness, which did not allow them room to act. The king stood on the top of the great temple, encouraging his men to exert themselves against the enemy. His words, however, had now lost their usual influence. He not only was not obeyed, but reproached with cowardice because he did not come down and fight amongst the rest. At last the Mexicans arrived at the temple, and ascended to the balcony where the king had taken his station. He made a desperate defence, but by a violent push in the breast he was thrown backwards upon the steps of the temple, and stunned or perhaps killed by the fall. The Tlatelolcos being thus reduced, Axaya-

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catl next set out on an expedition against the Matlazincas, a tribe in the valley of Toluca, who still refused to submit to the Mexican yoke. Having proved successful in this expedition, he undertook to subdue also the northern part of the valley, afterwards called Valle d'Ixtlahucan, particularly Xiquipilco, a considerable city and state of the Otomies, whose chief was much renowned for strength and bravery. Axayacatl, who likewise valued himself upon these qualities, encountered him in single combat. In this, however, he was overmatched, and received a violent wound in the thigh, after which he would have been taken prisoner, had not some young Mexicans made a desperate effort for his rescue. Notwithstanding this disaster, Axayacatl's army gained a complete victory, carrying off more than eleven thousand prisoners amongst whom was the chief of the Otomies himself, and two of his officers who had attacked the king. These chiefs were put to death at an entertainment of the allied kings, the sight of their agonies not interrupting in the least the mirth of the feast.

Axayacatl succeeded by Tizoc.

Axayacatl was succeeded by his elder brother called Tizoc. He intended to have built a larger temple than any which had yet been seen in Mexico, although that originally built had been greatly enlarged by some of his predecessors. For this purpose he collected a great quantity of materials; but before he could bring his projects to bear, he was taken off by a conspiracy of his subjects. During the reign of Tizoc, the Acolhuacans made war upon the Huexotzincas, ruined their city, and conquered their territory. Nezahualpilli, also, the Acolhuacan monarch, although he had already several wives, had not made any of them queen, having wished to confer that honour upon one of the royal family of Mexico. Tizoc readily gave him one of his grand-daughters, who had a sister of singular beauty named Xocotzin. The friendship between these two ladies was such, that the one could not think of being separated from the other; and for this reason the new queen sought and obtained permission to take her sister along with her to Tezcuco. Xocotzin had not been long there before the king fell in love with her, and married her with the title of queen. Soon after this second marriage, the first queen brought forth a son named Cacamatzin, who succeeded him in the throne, and was afterwards taken prisoner by the Spaniards.

Ahuitzotl.

Ahuitzotl, the brother of Tizoc, succeeded him in the kingdom of Mexico. His first object was to finish the great temple begun by his predecessor; and so great was the number of workmen employed, that it was completed in four years. During the time it was building, the king employed himself in making war with different nations, reserving all the prisoners he took for victims at the dedication of the temple. The number of prisoners sacrificed at this dedication is said by Torquemada to have been 72,324, and by other historians is estimated at 64,060. The miserable victims were ranged in two files, each a mile and a half in length, terminating at the temple. The same year another temple was built by a feudatory lord, in imitation of the great one built by the king; and at the dedication of it a vast number of prisoners were also sacrificed. These temples were dedicated in 1486. In 1487 there happened a violent earthquake; and Chimalpopoca king of Acolhuacan having died was succeeded by Totoquihuatzin II. Ahuitzotl died in the year 1502, of a disorder produced by a contusion in the head. At the time of his death, the Mexican empire was brought to its utmost extent.

Montezuma.

His successor, Montezuma Xocojotzin or Montezuma Junior, was a person of great bravery, besides which he was likewise a priest, and held in great estimation on account of his gravity and the dignity of his deportment. His election was unanimous; and the nobles congratulated themselves on the happiness the country was to enjoy under him, little thinking how short the duration of their happiness or of their empire was to be. The first care of the new monarch was, as usual, to procure victims for the barbarous sacrifices to be made at his coronation. The people of Atlixco, who had again shaken off the Mexican yoke, were the sufferers on this occasion, being once more reduced, though not without great loss on the part of the Mexicans, some of whose bravest officers perished in the war. The ceremony of coronation was performed with such pomp as had never been seen before in Mexico; but no sooner was this ceremony terminated than Montezuma began to discover a pride which nobody had before suspected. All his predecessors had been accustomed to confer offices upon persons of merit, and those who appeared the most able to discharge them, without any partiality as to birth or wealth. Montezuma, however, disapproved of the conduct of his predecessors, on the pretence that the plebeians should be employed according to their rank; and he deprived all the commoners of the offices they held about the court, declaring them incapable of holding any for the future. All the royal servants were now people of rank. Besides those who lived in the palace, six hundred feudatory lords and nobles came to pay court to him. They passed the day in the antichamber, where none of their servants were permitted to enter, conversing in a low voice, and waiting the orders of their sovereign. The servants of these lords were so numerous that they occupied three small courts of the palace, whilst many waited in the streets.

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Magnificence displayed in his palace.

In every respect Montezuma kept up, as far as was possible, an extravagant appearance of dignity. His kitchen utensils were of the finest earthen ware, and his tablecloths and napkins of the finest cotton; but none of these ever served the emperor oftener than once, being immediately presented to some nobleman. The vessels in which his chocolate and other drinks from cocoa were prepared, were all of gold, or some beautiful sea-shell, or naturally-formed vessels, curiously varnished. He had also gold plate, but it was used only upon particular occasions in the temple. The number and variety of his dishes astonished the Spaniards. He took great delight in the cleanliness of his person, and of every thing about him. He bathed regularly every day, and had baths in all his palaces. Every day he wore four dresses, never using again those which he had put off, but reserving them as largesses for the nobility, or those who had distinguished themselves in war. The expence of all this rendered him very disagreeable to a great number of his subjects; though others were pleased with the readiness he shewed to relieve the necessities of individuals, and his generosity in rewarding his generals and ministers.

Unsuccessful war with Tlascala.

The reign of Montezuma, even before the arrival of the Spaniards, was far from being so glorious as those of his predecessors had been. He reduced indeed one rebellious province, and conquered another which had never before been subjugated; but in his war with Tlascala he was by no means successful. This was a small republic at no great distance from the capital, and the inhabitants were remarkable for their bravery and independent spirit. The neighbouring states, however, who had been reduced by the Mexicans, envious of their liberty and prosperity, exasperated the Mexicans against them, by representing that the Tlascalans were desirous of making themselves masters of the maritime provinces on the Mexican Gulf, and that by their commerce with these provinces they were increasing their wealth and power, and gaining the hearts of the people with whom they were to traffic. In consequence of this representation, strong garrisons were placed on the frontiers of Tlascala, to obstruct the commerce of the inhabitants, and thus to deprive them of the means of obtaining some of the necessaries of life. The Tlascalans complained, but received no other answer than that the king of Mexico was lord of all the world, and that the Tlascalans must submit and pay tribute to him. The Tlascalans returned a spirited answer to this insolent speech,

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and began to fortify their frontier. They had already enclosed all the lands of the republic with intrenchments, to which they now added a wall of six miles in length on the west side, where an invasion was most to be apprehended; and so well did they defend themselves, that though they were frequently attacked by the neighbouring states in alliance with Mexico, or subject to it, not one of them was able to wrest a foot of ground from them.

Apprehensions of the arrival of a new people.

During the remainder of Montezuma's reign the empire was disturbed by various rebellions, of which the accounts are not sufficiently interesting to merit particular detail; but in the year 1508, Montezuma began to entertain apprehensions of that fatal event which at length overtook him. An expedition having been undertaken against a very distant region named Amatla, the army in marching over a lofty mountain were attacked by a furious north wind, accompanied with snow, which made great havoc amongst the troops, many of them perishing with cold, and others being killed by the trees rooted up by the wind. The remains of the army continued their march to Amatla, where they were almost all killed in battle. By this and other calamities, together with the appearance of a comet, the Mexicans were thrown into the utmost consternation. Montezuma was so terrified by these omens, that having in vain consulted his astrologers, he applied to the king of Alcohuacan, who was reported to be very skilful in divination. Nezahualpilli having conferred with him upon the subject, told Montezuma that the comet presaged some calamity which was about to befal their kingdoms by the arrival of a new people; but this being unsatisfactory to the emperor, the king of Alcohuacan challenged him to a game at foot-ball, staking the truth of his prediction on the issue of the game. Montezuma lost the game, but did not yet acquiesce in the truth of his prediction. He therefore applied to a celebrated astrologer, whom it seems he had not yet consulted, and who confirmed the interpretation of Nezahualpilli; and the emperor was so displeased that he caused his house to be pulled down, and himself to be buried in the ruins.

Conquest of Mexico undertaken by Cortez.

Mexico itself was originally discovered, though imperfectly, by a Spaniard named Nunez de Bilboa; but in 1518 the conquest of it was undertaken by a celebrated adventurer named Fernando Cortez. On the 10th of February 1519, he set sail from the Havannah in Cuba, and soon landed on the island of Cozumel, on the coast of Yucatan, discovered the preceding year. Here he joined one of his officers named Pedro d'Alvaredo, who had arrived several days before, and collected some booty and taken a few prisoners. But the general severely censured his conduct; and the prisoners were dismissed, after they had been informed by an Indian interpreter named Melchior, that such injuries were entirely disagreeable to the intentions and wishes of Cortez. Here he mustered his army, and found that it amounted to five hundred and eight soldiers, sixteen horsemen, and one hundred and nine mechanics, pilots, and mariners. Having encouraged his men by a proper speech, and released, by means of some Indian ambassadors, a Spaniard named Jerom de Aguilar, who had been detained a prisoner for eight years, he proceeded to the river Tabasco, where he hoped to be received in a friendly manner, as one Grijalva had been a short time before; but, from some unknown cause, he was violently attacked. The superiority of the Spanish arms, however, soon decided the victory in their favour, and the inhabitants were obliged to own the king of Castille as their sovereign. The Spaniards then continued their course westwards, to the harbour of St. Juan de Ulloa, where they were met by two Mexican canoes, which carried two ambassadors from the emperor of that country, and showed the greatest signs of peace and amity. Their language was unknown to Aguilar; but one of the female prisoners above mentioned understood it, and translated it into the Yucatan tongue; after which Aguilar interpreted the meaning in Spanish. This slave was afterwards named Donna Marina, and proved very useful in their conferences with the natives.

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State of the empire at this time.

At this time the Mexican empire, according to Robertson, had arrived at a pitch of grandeur to which no society had ever attained in so short a period. Though it had subsisted only for a hundred and thirty years, its dominion extended from the north to the south sea, over territories stretching about 500 leagues from east to west, and more than 200 from north to south; comprehending provinces not inferior in fertility, population, and opulence, to any in the torrid zone. Though by nature Montezuma possessed a good deal of courage and resolution, yet from the first moment that the Spaniards appeared upon his coast, he discovered symptoms of timidity and embarrassment, and all his subjects were embarrassed as well as himself. The general dismay which prevailed upon this occasion was partly owing to the strange figure the Spaniards made, and the prodigious power of their arms; but partly also attributable to another circumstance. An opinion prevailed almost universally amongst the Americans, that some dreadful calamity impended over their heads, from a race of formidable invaders who should come from regions towards the rising sun, to overrun and desolate their country.

Proceedings of Cortez.

By means of his two interpreters, Donna Marina and Aguilar, Cortez learned that the chiefs of the Mexican embassy were deputies from Pilpatoe and Teutile; the one governor of a province under the emperor, and the other the commander of all his forces in that province. The purport of their embassy was to inquire what his intentions were in visiting their coasts, and to offer him what assistance he might need in order to continue his voyage. Cortez, in his turn, also professed the greatest friendship; and informed the ambassadors, that he came to propose matters of the utmost consequence to the welfare of the prince and his kingdom; which he would more fully unfold in person to the governor and the general. Next morning, without waiting for any answer, he landed his troops, horses, and artillery, and began to erect huts for his men, and to fortify his camp. The day following the ambassadors had a formal audience, at which Cortez acquainted them, that he came from Don Carlos of Austria, king of Castille, the greatest monarch of the east, and was intrusted with propositions of such moment that he would impart them to none but the emperor himself, and therefore required to be conducted immediately to the capital. This demand produced the greatest uneasiness; and the ambassadors did all in their power to dissuade Cortez from his design, endeavouring to conciliate his good will by the presents sent him by Montezuma. These which were introduced with great parade, consisted of fine cotton cloth, of plumes of various colours, and of ornaments of gold and silver to a considerable value, the workmanship of which appeared to be as curious as the materials were rich. But these presents served only to excite the avidity of the Spaniards, and to increase their desire for becoming masters of a country which abounded with so many precious commodities. Cortez indeed, could scarcely restrain himself so far as to hear the arguments made use of by the ambassadors to dissuade him from going to the capital; and, in a haughty, determined tone, insisted on his former demand of being admitted to a personal interview with their sovereign. During this conversation, some painters in the retinue of the Mexican chiefs had been diligently employed in delineating, upon white cotton cloths, figures of the ships, horses, artillery, soldiers, and whatever else attracted their eyes as singular.

Montezuma informed of the designs of the invaders.

Whilst picture-writers were exerting their utmost efforts in representing all these wonderful things, messengers were immediately despatched to Montezuma with the paintings containing an account of every thing that had passed since the arrival of the Spaniards, together with some European

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curiosities, which Cortez believed would be acceptable to Montezuma on account of their novelty. The Mexican monarchs had couriers posted at proper stations along the principal roads; and as these were trained to agility by a regular education, they conveyed intelligence with surprising rapidity. Though the city in which Montezuma resided was above 180 miles distant from St. Juan de Ulloa, Cortez's presents were carried thither, and an answer returned to his demands in a few days. As the answer was unfavourable, Montezuma had endeavoured to mollify the Spanish general by the richness of his presents. These consisted of the manufactures of the country; cotton stuffs so fine, and of such delicate texture, as to resemble silk; and pictures of animals, trees, and other natural objects, formed with feathers of different colours, disposed and mingled with such skill and elegance as to rival the works of the pencil in truth and beauty of imitation. But what chiefly attracted their attention, were two large plates of a circular form; one of massive gold representing the sun, and the other of silver representing the moon. These were accompanied with bracelets, collars, rings, and other trinkets of gold; and that nothing might be wanting which could give the Spaniards a complete idea of what the country afforded, some boxes filled with pearls, precious stones, and grains of gold unwrought, as they had been found in the mines or rivers, were sent along with the rest. Cortez received all with an appearance of the most profound respect for Montezuma; but when the Mexicans, presuming upon this, informed him, that their master, though he desired him to accept of what he had sent as a token of his regard for the prince whom he represented, would not give his consent that foreign troops should approach nearer to his capital, or even allow them to continue longer in his dominions, Cortez declared in a manner more resolute and peremptory than formerly, that he must insist on his first demand, as he could not, without dishonour, return to his own sovereign until he was admitted into the presence of the prince whom he was appointed to visit in his name.

Montezuma commands Cortez to leave his dominions.

The pusillanimity of the Indian monarch afforded time to the Spaniards to take measures which would have been out of their power had they been vigorously attacked on their first refusal to obey his orders. Cortez used every method of securing the affections of the soldiers, which indeed was the more necessary, as many of them had begun to exclaim against the rashness of his attempt in leading them against the whole force of the Mexican empire. In a short time Teutile arrived with another present from Montezuma, and together with it delivered the ultimate orders of that monarch to depart instantly out of his dominions; and when Cortez, instead of complying with his demands, renewed his request of audience, the Mexican immediately left the camp with strong marks of surprise and resentment. Next morning, none of the natives appeared; all friendly correspondence seemed to be at an end, and hostilities were expected to commence every moment. A sudden consternation ensued amongst the Spaniards, and a party was formed against Cortez by the adherents of Velasquez, who, taking advantage of the occasion, deputed one of their number, a principal officer, to remonstrate, as if in the name of the whole army, against his rashness, and to urge the necessity of his returning to Cuba. Cortez received the message without any appearance of emotion; and as he well knew the temper and wishes of his soldiery, he pretended to comply with the request made him, and issued orders that the army should be in readiness next day to embark for Cuba. Upon hearing this, the troops, as Cortez had expected, were quite outrageous; they positively refused to comply with these orders, and threatened immediately to choose another general if Cortez continued to insist on their departure. Pleased with the disposition which now appeared amongst his troops, but dissembling his sentiments, he declared, that his orders for embarking had proceeded from a persuasion that it was agreeable to his fellow-soldiers, to whose opinion he had sacrificed his own; but now he acknowledged his error, and was ready to resume his original plan of operation. This speech was highly applauded; and Cortez, without allowing his men time to cool, immediately set about carrying his designs into execution. In order to give a beginning to a colony, he assembled the principal persons in his army, and by their suffrages elected a council and magistrates, in whom the government was to be vested. The persons chosen were most firmly attached to Cortez; and the new settlement received the name of Villa Rica de la Vera Cruz, that is, the rich town of the true cross.

The government of the new colony vested in Cortez.

Before this court of his own making, Cortez did not hesitate at resigning all his authority, and was immediately re-elected chief-justice of the colony, and captain-general of his army, with an ample commission, in the king's name, to continue in force till the royal pleasure should be further known. The soldiers eagerly ratified their choice by loud acclamations; and Cortez, now considering himself as no longer accountable to any subject, began to assume a much greater degree of dignity, and to exercise more extensive powers than he had hitherto done. Cortez having thus strengthened himself as well as he could, resolved to advance into the country; and to this he was encouraged by the behaviour of the cacique or petty prince of Zempoalla, a considerable town at no great distance. Here he was received in the most friendly manner imaginable, and had a respect paid towards him almost equivalent to adoration. The cacique informed him of many particulars relating to the character of Montezuma. He told him that he was a tyrant, haughty, cruel, and suspicious, who treated his own subjects with arrogance, ruined the conquered provinces by his extortions, and often tore their sons and daughters from them by violence; the former to be offered as victims to his gods, the latter to be reserved as concubines for himself and favourites. Cortez, in reply, artfully insinuated, that one great object of the Spaniards in visiting a country so remote from their own was, to redress grievances, and to relieve the oppressed; and having encouraged him to hope for this interposition in due time, continued his march to Quiabislan, the territory of another cacique, where, by the friendly aid of the Indians, a Spanish colony was soon formed.

Policy of Cortez.

During the residence of Cortez in these parts, he so far wrought on the minds of the caciques of Zempoalla and Quiabislan, that they ventured to insult the Mexican power, at the very name of which they had formerly been accustomed to tremble. Some of Montezuma's officers having appeared to levy the usual tribute, and to demand a certain number of human victims, as an expiation of their guilt in presuming to hold intercourse with those strangers whom the emperor had commanded to leave his dominions; instead of obeying his orders, they made them prisoners, treated them with great indignity, and, as their superstition was no less barbarous than Montezuma's, they threatened to sacrifice them to their gods. Though Cortez had now taken such measures as in a manner ensured his success, yet as he had thrown off all dependence on the governor of Cuba, who was his lawful superior, and apprehended his interest at court, he thought proper, before he set out on his intended expedition, to take the most effectual measures against the impending danger. With this view, he persuaded the magistrates of his colony to address a letter to the king, containing a pompous account of their own services, of the country they had discovered, and of the motives which had induced them to throw off their allegiance to the governor of Cuba, and to settle a colony dependent on the crown alone, in which the supreme power, civil as well as military, had been vested in Cortez; humbly requesting their sovereign to ratify what had been done by his royal authority.

Some soldiers and sailors, secretly disaffected to Cortez, Conspiracy

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formed a design of seizing one of the brigantines, and making their escape to Cuba, in order to give such intelligence to the governor as might enable him to intercept the vessel which was to carry the treasure and despatches to Spain. This conspiracy was conducted with profound secrecy; but at the moment when every thing was ready for execution, the secret was discovered by one of the associates. The latent spirit of disaffection which Cortez now became convinced had not been extinguished amongst his troops, gave him great uneasiness. The only method he could think of to prevent such conspiracies for the future, was to destroy his fleet, and thus deprive his soldiers of every resource except that of conquest; and with this proposal he persuaded his men to comply. The ships were therefore drawn ashore, and, after being stripped of their sails, rigging, iron work, and whatever else might be of use, they were broken in pieces. Cortez having thus rendered it necessary for his troops to follow wherever he chose to lead, began his march to Zempoalla with five hundred infantry, fifteen horse, and six field pieces. The rest of his troops being less fit for active service, he left them as a garrison in Villa Rica, under the command of Escalante, an officer of merit, and warmly attached to his interest. The cacique of Zempoalla supplied him with provisions, and with two hundred of those Indians called Tamanes, whose office, in a country where tame animals were unknown, was to carry burdens, and perform all manner of servile labour. He offered likewise a considerable body of troops; but Cortez was satisfied with four hundred, taking care, however, to choose persons of such note, that they might serve as hostages for the fidelity of their master.

Cortez sends ambassadors to the republic of Tlascala.

Nothing memorable happened till the Spaniards arrived on the confines of the republic of Tlascala. The inhabitants of that province were warlike, fierce, and revengeful, and had made considerable progress in agriculture and some other arts. They were implacable enemies of Montezuma, and therefore Cortez hoped that it would be an easy matter for him to procure their friendship. With this view, four Zempoallans of high rank were sent as ambassadors to Tlascala, dressed with all the badges of that office usual amongst the Indians. The senate were divided in their opinions with regard to the proposals of Cortez; but at last Magiscatzin, one of the oldest senators, and a person of great authority, mentioned the tradition of their ancestors, and the revelations of their priests, that a race of invincible men, of divine origin, who had power over the elements, should come from the east to subdue their country. He compared the resemblance which the strangers bore to the persons figured in the traditions of Mexico, their dominion over the elements of fire, air, and water; he reminded the senate of their prodigies, omens, and signals, which had lately terrified the Mexicans, and indicated some very important event; and he then declared his opinion that it would be rashness to oppose a force apparently assisted by heaven, and men who had already proved, to the sad experience of those who opposed them, that they were invincible. This orator was opposed by Xicotencal, who endeavoured to prove that the Spaniards were at best but powerful magicians; that they had rendered themselves obnoxious to the gods by pulling down their images and altars, and that they might easily be overcome, as the gods would not fail to resent such an outrage. He therefore voted for war, and advised the crushing of these invaders at one blow.

War with that people.

The advice of Xicotencal prevailed, and the ambassadors were detained, which gave Cortez great alarm, and induced him to approach the city of Tlascala. The inhabitants suffered him with his army drawn up in good order, to pass a strong wall between two mountains, which might have been very advantageously defended against him. But he had not advanced far beyond this pass, when a party of Tlascalans with plumes were discovered, which denoted that an army was in the field. These he drove before him by a detachment of six horse; obliged them to join another party; and then reinforcing the advanced detachment, charged the enemy with such vigour that they began to retire. Five thousand Tlascalans then rushed out of their hiding places, just as the infantry came up in order to assist their slender body of cavalry. The enemy attacked with the utmost fury, but were so much disconcerted by the first discharge of the fire-arms, that they retreated in confusion, furnishing the Spaniards with an opportunity of pursuing them with great slaughter. Cortez, however, supposing that this could not be their whole force, advanced with the utmost caution, in order of battle, to an eminence, whence he had a view of the main body of the Tlascalan army, commanded by Xicotencal, consisting of not fewer than 40,000 men. By these the small army of Cortez was entirely surrounded; which Xicotencal no sooner perceived, than he contracted the circle with incredible diligence, whilst the Spaniards were almost overwhelmed with showers of arrows, darts, and stones. It is impossible but in this case many of the Spaniards would have perished, had it not been for the insufficiency of the Indian weapons. This circumstance gave the Spaniards a prodigious advantage over them; and therefore the Tlascalans, notwithstanding their valour and superiority in number, could accomplish no more in the present instance than killing one horse and slightly wounding nine soldiers. The Tlascalans, taught by this, and some subsequent encounters, how much they were inferior to the Spaniards, began to conceive them to be really what Magiscatzin had said, a superior order of beings, against whom human power could not prevail. In this extremity they had recourse to their priests, requiring them to reveal the causes of such extraordinary events, and to declare what means they should take to repel such formidable invaders. The priests, after many sacrifices and incantations, delivered their response, that these strangers were the offspring of the sun, procreated by his animating energy in the regions of the east; that by day, whilst cherished with the influence of his parental beams, they were invincible; but that by night, when his reviving heat was withdrawn, their vigour declined, and faded like herbs in the field, and they dwindled down into mortal men. In consequence of this, the Tlascalans acted in contradiction to one of their most established maxims in war, and ventured to attack the enemy in the night time, hoping to destroy them when enfeebled and surprised. But the Spanish sentinels having observed some extraordinary movements amongst the Tlascalans, gave the alarm. Immediately the troops were under arms, and sallying out, defeated their antagonists with great slaughter, without allowing them to approach the camp. By this disaster the Tlascalans were heartily disposed to peace; but they were at a loss to form an adequate idea of the enemies whom they had to deal withal. They could not ascertain the nature of these surprising beings, or whether they were really of a benevolent or malignant disposition. There were circumstances in their behaviour which seemed to favour either opinion. On the one hand, as the Spaniards constantly dismissed the prisoners whom they took, not only without injury, but often with presents of European toys, and renewed their offers of peace after every victory; this lenity amazed people accustomed to the exterminating system of war known in America, and disposed them to entertain sentiments favourable to their humanity. But, on the other hand, as Cortez had seized fifty of their countrymen who brought provisions to their camp, and cut off their heads; this bloody spectacle, added to the terror occasioned by the fire-arms and horses, filled them with dreadful ideas of the ferocity of the invaders. Peace, however, was soon concluded, to the great satisfaction of both parties. The Tlascalans yielded themselves as vassals to the crown of Castille, and engaged to assist Cortez in all his operations; whilst he took the republic under his pro-

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Cortez prosecutes his enterprise.

tection, and promised to defend their persons and possessions from injury and violence.

Cortez left no method untried to gain the favour and confidence of the Tlascalans; which, however, he had almost entirely lost, by his untimely zeal in destroying their idols, as he had done those of Zempoalla. But he was deterred from this rash action by his chaplain father Bartolomeo de Olmedo, and left the Tlascalans in the undisturbed exercise of their superstition, requiring only that they should desist from their horrid practice of offering human victims. As soon as his troops were fit for service, he resolved to continue his march towards Mexico, notwithstanding the remonstrances of the Tlascalans, who looked upon his destruction as inevitable if he put himself into the power of such a faithless prince as Montezuma. But the emperor, probably intimidated by the fame of his exploits, had resolved to admit his visit, and informed Cortez that he had given orders for his friendly reception at Cholula, the next place of any consequence on the road to Mexico. Cortez was received with much seeming cordiality; but six thousand Tlascalan troops who accompanied him were obliged to remain without the town, as the Cholulans refused to admit their ancient enemies within their precincts. Yet two of these, by disguising themselves, got into the city, and acquainted Cortez that they had observed the women and children belonging to the principal citizens retiring every night in a great hurry; and that six children had been sacrificed in the great temple, a sign that some warlike enterprise was in contemplation. At the same time Donna Marina, the interpreter, received information from an Indian woman of distinction, whose confidence she had gained, that the destruction of the Spaniards was concerted; that a body of Mexican troops lay concealed near the town; that some of the streets were barricaded, whilst in others deep pits or trenches were dug, and slightly covered over, as traps into which the horse might fall; that stones and missile weapons were collected upon the tops of the temples, with which to overwhelm the infantry; and that the fatal hour was already at hand, and their ruin inevitable. Cortez, alarmed at this news, secretly arrested three of the chief priests, from whom he extorted a confession, which confirmed the intelligence he had already received. As not a moment was to be lost, he instantly resolved to anticipate his enemies, and to inflict upon them such dreadful vengeance as might strike Montezuma and his subjects with terror. On a signal given, the troops rushed out, and fell upon the multitude, who, destitute of leaders, were so much astonished, that the weapons dropped from their hands, and they stood motionless, and incapable of defence. Whilst the Spaniards attacked them in front, the Tlascalans did the same in the rear; the streets were filled with slaughter, and the temples, which afforded a retreat to the priests and some leading men, were set on fire, in consequence of which they perished in the flames. At length the carnage ceased, after the slaughter of six thousand Cholulans, without the loss of a single Spaniard. Cortez then released the magistrates, and, reproaching them bitterly for their intended treachery, declared, that as justice was now appeased, he forgave the offence; but required them to recal the inhabitants who had fled, and to re-establish order in the town.

Disaffection of Montezuma's subjects.

From Cholula, Cortez advanced directly towards Mexico; and throughout the whole of his journey was entertained with accounts of the oppressions and cruelty of Montezuma. This gave him the greatest hope of accomplishing his design, as he now perceived that the empire was entirely divided, and that no sort of unanimity prevailed amongst them. No enemy appeared to check his progress. Montezuma was quite irresolute; and Cortez had almost arrived at the gates of the capital before the emperor had determined whether to receive him as a friend or to oppose him as an enemy. But as no sign of open hostility appeared, the Spaniards, without regarding the fluctuations of Montezuma's sentiments, continued their march to Mexico, with great circumspection and the strictest discipline, though without seeming to suspect the prince whom they were about to visit.

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Meeting of Cortez and Montezuma.

When they drew near to the city, about one thousand persons of distinction came forth to meet them, adorned with plumes, and clad in mantles of fine cotton. Each of these, in his order, passed by Cortez, and saluted him according to the mode of their country. They announced the approach of Montezuma himself, and soon after his harbingers came in sight. There appeared first two hundred persons in an uniform dress, with large plumes of feathers, alike in fashion, marching two and two, in profound silence, barefooted, with their eyes fixed on the ground. These were followed by a company of higher rank, in their most showy apparel; in the midst of whom was Montezuma, in a chair or litter richly ornamented with gold and feathers of various colours. Four of his principal favourites carried him on their shoulders, and others supported a canopy of curious workmanship over his head. Before him marched three officers with rods of gold in their hands, which they lifted up on high at certain intervals; and at that signal all the people bowed their heads, and hid their faces, as unworthy to look upon so great a monarch. When he drew near, Cortez dismounting, advanced towards him in a very respectful manner. At the same time Montezuma alighted from his chair, and leaning on the arms of two of his near relations, approached with a slow and stately pace; his attendants covering the streets with cotton cloths, that he might not touch the ground. Cortez accosted him with profound reverence, after the European fashion. He returned the salutation, according to the mode of his country, by touching the earth with his hand, and then kissing it. Nothing material passed at this first interview. Montezuma conducted Cortez to the quarters which had been prepared for his reception, and immediately took leave of him with a politeness not unworthy of a more refined court. "You are now," said he, "with your brothers, in your own house; refresh yourselves after your fatigue, and be happy until I return." The first care of Cortez was to take precautions for his security, by planting the artillery so as to command the different avenues which led to it; by appointing a large division of his troops to be always on guard; and by posting sentinels at proper stations, with injunctions to observe the same vigilant discipline as if they were actually within sight of an enemy's camp. In the evening Montezuma returned to visit his guests with the same pomp as in their first interview, and brought presents of such value, not only to Cortez and to his officers, but even to the private men, as proved the liberality of the monarch to be suitable to the opulence of his kingdom. A long conference ensued, in which Cortez learned the opinion of Montezuma respecting the Spaniards. Next morning, Cortez and some of his principal attendants were admitted to a public audience of the emperor. The three subsequent days were employed in viewing the city, the appearance of which, so far superior in the order of its buildings and the number of its inhabitants to any place the Spaniards had beheld in America, and yet so little resembling the structure of an European city, filled them with surprise and admiration.

The city of Mexico.

Mexico is situated in a large plain, environed by mountains of such height, that although within the torrid zone, the temperature of its climate is mild and healthful. All the moisture which descends from the high grounds is collected in several lakes, the two largest of which, about ninety miles in circumference, communicate with each other. The waters of the one are fresh, those of the other are brackish. On the banks of the latter, and on some small islands adjoining to them, the capital of Montezuma's empire was built. The access to the city was by artificial causeways or streets, formed of stones and earth, about thirty feet in breadth. As the waters of the lake, during the rainy season, overflowed the level country, these causeways were of consider-

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able length; that of Tacuba, on the west, being a mile and a half; that of Tezcuco on the north-west, three miles; and that of Cuoyacan towards the south, six miles. On the east there was no causeway, and the city could be approached only by canoes. In each of the causeways there were openings at proper intervals, through which the waters flowed; and over these beams of timber were laid, which being covered with earth, the causeway or street had everywhere an uniform appearance. As the approaches to the city were singular, its construction was remarkable. Not only the temples of their gods, but the houses belonging to the monarch, and to persons of distinction, were of such dimensions, that in comparison with any other buildings which had been discovered in America, they might even be termed magnificent. The habitations of the common people were mean, resembling the huts of other Indians; but they were all placed in a regular manner, on the banks of the canals which passed through the city, in some of its districts, or on the sides of the streets which intersected it in other quarters. In several places there were large openings or squares, one of which, allotted for the great market, is said to have been so spacious that forty or fifty thousand persons carried on traffic there. In this city, the pride of the New World, and the noblest monument of the industry and the art of man, whilst unacquainted with the use of iron, the Spaniards, who are most moderate in their computations, reckon that there were at least sixty thousand inhabitants.

Uneasiness of the Spaniards.

But how much soever the novelty of those objects might amuse or astonish the Spaniards, they felt the utmost solicitude with respect to their own situation. From a concurrence of circumstances, no less unexpected than favourable to their progress, they had been allowed to penetrate into the heart of a powerful kingdom, and were now lodged in its capital, without having once met with open opposition from its monarch. The Tlascalans, however, had earnestly dissuaded them from placing such confidence in Montezuma as to enter a city so peculiarly situated as Mexico, where that prince would have them at mercy, shut up as it were in a snare, from which it was impossible to escape. They assured them that the Mexican priests had, in the name of their gods, counselled their sovereign to admit the strangers into the capital, that he might cut them off there at one blow with perfect security. The Spaniards now perceived, too plainly, that the apprehensions of their allies were not destitute of foundation; that, by breaking the bridges placed at certain intervals on the causeways, or by destroying part of the causeways themselves, their retreat would be rendered impracticable; and that they would remain cooped up in the centre of a hostile city, surrounded by multitudes sufficient to overwhelm them, without a possibility of receiving aid from their allies.

Hostilities between the Spaniards and Mexicans.

Before he set out from Cholula, Cortez had received advice from Villa Rica, that Qualpopoca, one of the Mexican generals on the frontiers, having assembled an army in order to attack some of the people whom the Spaniards had encouraged to throw off the Mexican yoke, Escalante had marched out with part of the garrison to support his allies; that an engagement had ensued, in which, though the Spaniards were victorious, Escalante, with seven of his men, had been mortally wounded, his horse killed, and one Spaniard had been surrounded by the enemy and taken alive; and that the head of this unfortunate captive, after being carried in triumph to different cities, in order to convince the people that their invaders were not immortal, had been sent to Mexico. Cortez, though alarmed with this intelligence, as an indication of Montezuma's hostile intentions, had continued his march. But as soon as he entered Mexico he became sensible that, from an excess of confidence in the superior valour and discipline of his troops, as well as from the disadvantage of having nothing to guide him in an unknown country, but the defective intelligence which he received from people with whom his mode of communication was very imperfect, he had pushed forward into a situation where it was difficult to continue, and from which it was dangerous to retire. Disgrace, and perhaps ruin, were the certain consequences of attempting a retreat. The success of his enterprise depended upon supporting the high opinion which the people of New Spain had formed with respect to the irresistible power of his arms. Upon the first symptom of timidity on his part, their veneration would cease, and Montezuma, whom fear alone had restrained, would let loose upon him the whole force of his empire. At the same time, he knew that the countenance of his own sovereign was to be obtained only by a series of victories, and that nothing but the merit of extraordinary success could screen his conduct from the censure of irregularity. From all these considerations, it was necessary to maintain his position, and to extricate himself out of the difficulties in which one bold step had involved him, by venturing upon another still bolder.

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Cortez resolves to seize Montezuma in his palace.

The situation was trying, but his mind was equal to the emergency; and after revolving the matter with deep attention, he fixed upon a plan no less extraordinary than daring. He determined to seize Montezuma in his palace, and to carry him as a prisoner to the Spanish quarters. From the superstitious veneration of the Mexicans for the person of their monarch, as well as their implicit submission to his will, he hoped, by having Montezuma in his power, to acquire the supreme direction of their affairs; or at least, with such a sacred pledge in his hands, he made no doubt of being secure from any effort of their violence. This he immediately proposed to his officers. The timid startled at a measure so audacious, and raised objections. The more intelligent and resolute, conscious that it was the only resource in which there appeared any prospect of safety, warmly approved of it, and brought over their companions so entirely to the same opinion, that it was agreed instantly to make the attempt. At his usual hour of visiting Montezuma, Cortez went to the palace, accompanied by Alvarado, Sandoval, Lugo, Velasquez de Leon, and Davila, five of his principal officers, and with as many trusty soldiers. Thirty chosen men followed, not in regular order, but sauntering at some distance, as if they had no object but curiosity; small parties were posted at proper intervals, in all the streets leading from the Spanish quarters to the court; and the remainder of his troops, with the Tlascalan allies, were under arms, ready to sally out upon the first alarm. Cortez and his attendants were admitted without suspicion; the Mexicans retiring, as usual, out of respect. He addressed the monarch in a tone very different from that which he had employed in former conferences, reproaching him bitterly as the author of the violent assault made upon the Spaniards by one of his officers, and demanding public reparation for the loss which he had sustained by the death of some of his companions, as well as for the insult which had been offered to the great prince whom they served. Montezuma, confounded at this unexpected accusation, and changing colour, either from the consciousness of guilt, or from feeling the indignity with which he was treated, asserted his own innocence with great earnestness; and, as a proof of it, gave orders instantly to bring Qualpopoca and his accomplices prisoners to Mexico. Cortez replied, with seeming complaisance, that a declaration so respectable left no doubt remaining in his own mind; but that something more was requisite to satisfy his followers, who would never be convinced that Montezuma did not harbour hostile intentions against them, unless, as an evidence of his confidence and attachment, he removed from his own palace and took up his residence in the Spanish quarters, where he should be served and honoured as became a great monarch. The first mention of so strange a proposal bereaved Montezuma of speech, and almost of motion. At length he haughtily answered, that persons of his rank were not accustomed to give themselves up voluntarily as prisoners;

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and that were he mean enough to do so, his subjects would not permit such an affront to be offered to their sovereign. Cortez, unwilling to employ force, endeavoured alternately to soothe and to intimidate him. The altercation became warm, and having continued above three hours, Velasquez de Leon, an impetuous and gallant young men, exclaimed with impatience, "Why waste more time in vain? Let us either seize him instantly, or stab him to the heart." The threatening voice and fierce gestures with which these words were uttered, struck Montezuma. The Spaniards, he was sensible, had now proceeded so far, as left him no hope that they would recede. His own danger was imminent, and the necessity unavoidable. He saw both; and abandoning himself to his fate, complied with their request. His officers were called. He communicated to them his resolution. Though astonished and afflicted, they presumed not to question the will of their master, but carried him in silent pomp, all bathed in tears, to the Spanish quarters.

Cortez rules the empire.

The Spaniards at first pretended to treat Montezuma with great respect, but soon took care to let him know that he was entirely in their power. Cortez wished that shedding the blood of a Spaniard should appear the most heinous crime that could be committed; and therefore he not only took a most exemplary vengeance on those who had been concerned in the affair of Villa Rica, but even put the emperor himself in chains until the execution of the Mexican general had taken place. By these, and other insults, he at last gained entirely the ascendant over this unhappy monarch; and he took care to improve his opportunity to the utmost. He sent his emissaries into different parts of the kingdom, accompanied with Mexicans of distinction, who might serve them both as guides and protectors. They visited most of the provinces, examined their soil and productions, surveyed with particular care the districts which yielded gold or silver, pitched upon several places as proper for future colonies, and endeavoured to prepare the minds of the people for submitting to the Spanish yoke; and whilst they were thus employed, Cortez, in the name and by the authority of Montezuma, degraded some of the principal officers in the empire, whose abilities or independent spirit had excited his jealousy, and substituted in their stead persons who he imagined would be more obsequious. One thing, however, was still wanting to complete his security. He wished to have such a command of the lake as might ensure a retreat, if, either from levity or disgust, the Mexicans should take arms against him, and break down the bridges or the causeways. In order to obtain this without giving disgust to the emperor or his court, Cortez artfully inflamed the curiosity of the Indians with accounts of the Spanish shipping, and those floating palaces which moved with such velocity on the water, without the assistance of oars; and when he found that the monarch himself was extremely desirous of seeing such a novelty, he gave him to understand, that nothing was wanting to his gratification excepting a few necessaries from Vera Cruz, as he had workmen in his army capable of building such vessels. The bait took with Montezuma; and he gave immediate orders that all his people should assist Cortez in whatever he should direct concerning the shipping. By this means, in a few days, two brigantines were got ready, full rigged and equipped; and Montezuma was invited to go on board and make the first trial of their sailing, of which he could form no idea. Accordingly he embarked for this purpose, and gave orders for a great hunting upon the water, in order that all his people might be diverted with the novelty presented by the Spaniards. On the day appointed, the royal equipage was ready early in the morning; and the lake was covered with a multitude of boats and canoes loaded with people. The Mexicans had augmented the number of their rowers on board the royal barges, with an intention to throw discredit upon the Spanish vessels, which they regarded as clumsy, unwieldy, and heavy. But they were soon undeceived. A fresh gale started up; the brigantines hoisted sail, to the utter astonishment of all the spectators, and soon left the canoes behind; whilst the monarch exulted in the victory of the Spaniards, without once considering that now he had effectually riveted his own chains.

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Cortez having obtained this important point, resolved to put the condescension of the emperor to a trial still more severe. He urged Montezuma to acknowledge himself a vassal of the crown of Castille; to hold his crown of him as superior; and to subject his dominions to the payment of an annual tribute. With this requisition, humiliating as it was, Montezuma complied. He called together the principal men of his empire, and, in a solemn harangue, reminded them of the traditions and prophecies which led them to expect the arrival of a people sprung from the same stock with themselves, in order to take possession of the supreme power; he declared his belief that the Spaniards were this promised race, and that, therefore, recognising the right of their monarch to govern the Mexican empire, he would lay his crown at his feet, and obey him as a tributary. Whilst uttering these words, Montezuma discovered how deeply he was affected in making such a sacrifice. Tears and groans frequently interrupted his discourse. The first mention of such a resolution struck the assembly dumb with astonishment; and this was followed by a sullen murmur of sorrow mingled with indignation, which indicated some violent explosion. Cortez foresaw the coming storm and seasonably interposed to prevent it, by declaring that his master had no intention to deprive Montezuma of the royal dignity, or to make any innovation upon the constitution and laws of the Mexican empire. This assurance, added to the dread of the Spanish arms, and the authority of their monarch's example, extorted the consent of the assembly; and the act of submission and homage was executed with all the formalities which the Spaniards pleased to prescribe.

Montezuma owns himself a vassal of Spain.

Montezuma, at the request of Cortez, accompanied this profession of fealty and homage with a magnificent present to his new sovereign; and, after his example, his subjects brought in very liberal contributions. The Spaniards then collected all the treasure which had been either voluntarily bestowed upon them at different times by Montezuma, or which had been extorted from his people under various pretences; and having melted the gold and silver, the value of both amounted to 600,000 pesos. The soldiers were impatient to have it divided; and Cortez complied with their desire. A fifth part of the whole was set aside as the tax due to the king, and another fifth was allowed to Cortez as commander. The sums advanced by the governor of Cuba, who had originally fitted out the expedition, were next deducted. The remainder was then divided amongst the army, including the garrison of Vera Cruz, in proportion to their different ranks; and after so many deductions, the share of a private man did not exceed one hundred pesos. This sum fell so far below their sanguine expectations, that it required all the address, and no small exertions of liberality on the part of Cortez, to prevent an open mutiny. However, he at last restored tranquillity; but no sooner had he escaped this danger, than by his imprudent zeal for religion, he involved himself in one much more dangerous.

The Spaniards divide their treasure.

Montezuma, although often importuned, had obstinately refused to change his religion, or abolish the superstitious rites which had been for such a long time practised throughout his dominions. This at last transported the Spaniards with such rage, that, in an ebullition of zeal, Cortez led out his soldiers in order to throw down by force the idols in the great temple. But the priests taking arms in defence of their altars, and the people crowding with great ardour to support them, the prudence of Cortez overruled his zeal, and induced him to desist from his rash attempt, after dislodging the idols from one of the shrines, and placing in their stead an

Cortez attempts to destroy the Mexican idols.

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image of the Virgin Mary. From this moment the Mexicans began to meditate the expulsion, if not the destruction, of the Spaniards. For this purpose the priests and leading men held frequent meetings with Montezuma. But as any violent attempt might have proved fatal to the captive monarch, it was thought proper first to try more gentle means. Having called Cortez into his presence, he observed, that now, as all the purposes of his embassy were fully accomplished, the gods had declared their will, and the people signified their desire, that he and his followers should instantly take their departure. With this he required them to comply, or unavoidable destruction would fall upon their heads. So unexpected a requisition, no less than the manner in which it was delivered, alarmed Cortez. However, he supposed that more might be gained by a feigned compliance than by open resistance, and therefore replied with great composure that he had already begun to prepare for his return; but as he had destroyed the vessels in which he arrived, some time was requisite for building other ships. This appeared reasonable; and a number of Mexicans were sent to Vera Cruz to cut down timber, and some Spanish carpenters were appointed to superintend the work.

An armament sent from Cuba against Cortez.

Cortez flattered himself, that during this interval, he might either find means to avert the threatened danger, or receive such reinforcements as would enable him to defend himself. Nine months had now elapsed since Portocarrero and Montejo had sailed with his despatches to Spain; and he daily expected a return, with a confirmation of his authority from the king, without which all that he had done would serve only to mark him out as an object of punishment. Whilst he remained in great anxiety on this account, news were brought that some ships had appeared on the coast. These were imagined by Cortez to be a reinforcement sent him from Spain; but his joy was of short continuance, for a courier very soon arrived from Vera Cruz, with certain information that the armament was fitted out by Velasquez, the governor of Cuba, and that instead of bringing succours, it threatened him with immediate destruction. Velasquez had been excited to this hostile measure chiefly through the indiscretion, or rather treachery, of the messengers of Cortez, who, contrary to his express injunctions, had landed on the island of Cuba, and given intelligence of all that had passed; and the governor, transported with rage at hearing the proceedings of Cortez, had now sent against him this armament, consisting of eighteen ships, which carried eighty horsemen, eight hundred infantry, of whom eighty were musketeers, and one hundred and twenty cross-bowmen, commanded by a brave officer named Pamphilo de Narvaez, whose instructions were, to seize Cortez and his principal officers, to send them prisoners to Velasquez, and then to complete the discovery and conquest of the country in his name. This proved a most afflicting piece of news to Cortez.

This armament defeated.

Having now no resource but in war, he left one hundred and fifty men under the command of Pedro de Alvarado, an officer of great bravery, and much respected by the Mexicans, to guard the capital and the captive emperor; whilst he himself marched with the remainder, to meet his formidable opponent, who had taken possession of Rempoalla. Even after being reinforced by Sandoval his governor of Vera Cruz, the force of Cortez did not exceed two hundred and fifty men. He hoped for success chiefly from the rapidity of his movements and the possibility of surprising his enemies; and as he chiefly dreaded their cavalry, he armed his soldiers with long spears, accustoming them to that deep, compact, and solid order which the use of this formidable weapon enabled them to assume. As he advanced, however, he repeated his proposals of accommodation; but these being constantly rejected, and a price set upon his head, he at last attacked Narvaez in the night time, and having entirely defeated and taken him prisoner, obliged all his troops to own allegiance to himself. Nothing could have been more seasonable than this victory, by which Cortez found his army very considerably increased; for most of the soldiers of Narvaez chose rather to follow Cortez than to return to Cuba, whither the conqueror had offered to send them if they chose.

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In the meantime, his affairs at Mexico were in the utmost danger of being totally ruined; and had this decisive victory been delayed but a few days longer, he must have arrived too late to save his companions. A short time after the defeat of Narvaez, a courier arrived from Mexico with the disagreeable intelligence that the Mexicans had taken arms, and having seized and destroyed the two brigantines which he had built in order to secure the command of the lake; had attacked the Spaniards in their quarters, killed some, wounded many more, and burned their magazine of provisions; and had, in short, carried on hostilities with such fury, that though Alvarado and his men defended themselves with undaunted resolution, they must either have been cut off by famine, or overpowered by the multitude of their enemies. This revolt was excited by motives which rendered it still more alarming. On the departure of Cortez for Zempoalla, the Mexicans flattered themselves, that the long-expected opportunity of restoring their sovereign to liberty, and of driving out the Spaniards, had arrived; and consultations were accordingly held for bringing about both these events. The Spaniards in Mexico, conscious of their own weakness, suspected and dreaded these machinations; but Alvarado, who had neither the prudence nor the address of Cortez, took the worst method imaginable to overcome them. Instead of attempting to soothe or cajole the Mexicans, he waited the return of one of their solemn festivals, when the principal persons in the empire were dancing, according to custom, in the court of the great temple; then he seized all the avenues which led to it, and, allured partly by the rich ornaments which they wore in honour of their gods, and partly by the facility of cutting off at once the authors of the conspiracy which he dreaded, he fell upon them, unarmed and unsuspicious of danger, and massacred a great number, none escaping but such as made their way over the battlements of the temple. An action so cruel and so treacherous filled not only the city, but the whole empire, with rage and indignation.

Dangerous situation of the Spaniards left at Mexico.

Cortez advanced with the utmost celerity to the relief of his distressed companions; but as he passed along, he had the mortification to find that the Spaniards were generally held in abhorrence. The principal inhabitants had deserted the towns through which he passed; no person of note appeared to meet him with the usual respect; nor were provisions as usual brought to his camp. Notwithstanding these signs of aversion and horror, however, the Mexicans were so ignorant of the military art, that they again permitted him to enter the capital without opposition; although they had it in their power to prevent him, by breaking down the bridges and causeways which led to it. Cortez was received by his companions with the utmost joy; and this extraordinary success had so far intoxicated the general himself, that he not only neglected to visit Montezuma, but expressed himself in contemptuous terms concerning him. These expressions being reported amongst the Mexicans, they suddenly flew to arms, and made such a violent and sudden attack, that all the valour and skill of Cortez were scarcely sufficient to repel them. This produced great uneasiness amongst the soldiers of Narvaez, who had imagined there was nothing to do but to gather the spoils of a conquered country. Discontent and murmurings, however, were no longer of any avail; they were enclosed in a hostile city, and, without some extraordinary exertions, were inevitably undone. Cortez, therefore, made a desperate sally; but, after exerting his utmost efforts for a whole day, he was obliged to retire with the loss of twelve killed, and upwards of

Cortez returns to Mexico, but is attacked by the natives.

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Death of Montezuma.

sixty wounded. Another sally was attempted with equal want of success, and in it Cortez himself was wounded in the hand.

The Spanish general being now thoroughly convinced of his error, betook himself to the only resource which remained; namely, to try what effect the interposition of Montezuma would have to soothe or overawe his subjects. When the Mexicans approached the next morning to renew the assault, that unfortunate prince, at the mercy of the Spaniards, and reduced to the sad necessity of becoming the instrument of his own disgrace, and of the slavery of his people, advanced to the battlements in his royal robes, and with all the pomp in which he used to appear upon solemn occasions. At the sight of their sovereign, whom they had been long accustomed to reverence almost as a god, the Mexicans instantly forebore their hostilities, and many prostrated themselves on the ground; but when he addressed them in favour of the Spaniards, and made use of all the arguments which he could think of to mitigate their rage, they testified their resentment with loud murmurings, and at length broke forth with such fury, that before the soldiers, appointed to guard Montezuma, had time to cover him with their shields, he was wounded with two arrows, and a blow on his temple with a stone struck him to the ground. On seeing him fall, the Mexicans instantly fled with the utmost precipitation, but the unhappy monarch, now convinced that he was become an object of contempt even to his own subjects, obstinately refused all nourishment, and thus in a short time ended his days.

Engagement between the Spaniards and Mexicans.

Upon the death of Montezuma, Cortez having lost all hope of bringing the Mexicans to any terms of peace, prepared for retreat. But his antagonists having taken possession of a high tower in the great temple, which overlooked the Spanish quarters, and placed there a garrison of their principal warriors, the Spaniards were so much exposed to their missile weapons, that none of them could stir without danger of being killed or wounded. From this post, therefore, it was necessary to dislodge them at any rate; and Juan de Escobar, with a large detachment of chosen soldiers, was ordered to make the attack. But Escobar, a valiant officer, although he exerted his utmost efforts, was thrice repulsed. Cortez, however, sensible that not only his reputation, but the safety of his army, depended upon the success of this assault, caused a buckler to be tied to his arm, as he could not manage it with his wounded hand, and rushed with his drawn sword amongst the thickest of the combatants. Encouraged by the presence of their general, the Spaniards returned to the charge with such vigour, that they gradually forced their way up the steps, and drove the Mexicans to the platform at the top of the tower. There a dreadful carnage commenced; upon which two young Mexicans of high rank, observing Cortez as he animated his soldiers, resolved to sacrifice their own lives in order to cut off the author of so many calamities which desolated their country. They approached him in a suppliant posture, as if they intended to lay down their arms, and seizing him in a moment, hurried him towards the battlements, over which they threw themselves headlong, in hopes of dragging him along with them. But Cortez by his strength and agility, disengaged himself from their grasp, and the devoted Mexicans perished alone. As soon as the Spaniards became masters of the tower, they set fire to it, and without further molestation continued the preparations for their retreat. This became the more necessary, as their enemies, astonished at this last effort of their valour, had now entirely changed their system of hostility, and, instead of incessant attacks, endeavoured, by barricading the streets, and breaking down the causeways, to cut off the communication of the Spaniards with the continent, and thus to starve an enemy whom they could not subdue. The first point to be determined, was whether they should march out openly in the face of day, when they could discern every danger, or whether they should endeavour to retire secretly in the night. The latter was preferred, partly from hopes that the superstition of the Mexicans would prevent them from attacking them in the night, and partly from their own superstition in giving credit to the predictions of a private soldier, who pretended to astrology, and assured them of success if they retreated in this manner.

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Towards midnight, therefore, they began their march in three divisions. Sandoval led the van; Pedro Alvarado and Velasquez de Leon had the conduct of the rear; and Cortez commanded in the centre, where he placed the prisoners, amongst whom were a son and two daughters of Montezuma, together with several Mexicans of distinction, the artillery, baggage, and a portable bridge of timber intended to be laid over the breaches in the causeway. They marched in profound silence along the causeway which led to Tacuba, because it was shorter than any of the rest, and, lying more remote from the road towards Tlascala and the sea coast, had been least injured by the Mexicans. They reached the first breach in the causeway without molestation, hoping that their retreat was undiscovered. The Mexicans, however, had not only watched all their motions, but had made preparations for a most formidable attack. Whilst the Spaniards were intent upon placing their bridges in the breach, and occupied in conducting their horses and artillery along it, they were suddenly alarmed with the sound of warlike instruments, and found themselves assaulted on all sides by an innumerable multitude of enemies. Unfortunately the wooden bridge became wedged so fast in the mud by the weight of the artillery, that it was found impossible to remove it. Dismayed at this accident, the Spaniards advanced with precipitation to the second breach. The Mexicans hemmed them in on every side; and although they defended themselves with their usual courage, yet, crowded as they were in a narrow causeway, their discipline and military skill were of little avail. Nor did the obscurity of the night allow them to derive much advantage from their firearms or from the superiority of their other weapons. At last the Spaniards, overborne with the numbers of their enemies, began to give way, and in a moment the confusion was universal. Cortez, with about a hundred foot soldiers, and a few horse, forced his way over the two remaining breaches in the causeway, the bodies of the dead serving to fill up the chasms, and reached the main land. Having formed them as soon as they arrived, he returned with such as were yet capable of service, to assist his friends in their retreat. He met with part of his soldiers who had forced their way through the enemy, but found many more overwhelmed by the multitude of their aggressors, or perishing in the lake; and he heard the grievous lamentations of others whom the Mexicans were carrying off in triumph to be sacrificed to the god of war. In this fatal retreat more than one half of Cortez's army perished, together with many officers of distinction. All the artillery, amunition, and baggage, were lost, the greater part of the horses and above two thousand Tlascalans were killed, and only a very small part of their treasure was saved. The first care of the Spanish general was to find some shelter for his wearied troops; for, as the Mexicans infested them on every side, and the people of Tacuba began to take arms, he could not remain in his present position. At last he discovered a temple seated on an eminence, in which he found not only the shelter he wanted, but also some provisions; and though the enemy did not intermit their attacks throughout the day, they were without much difficulty prevented from making any impression. For six days afterwards, they continued their march through a barren, ill-cultivated, and thinly-peopled country, where they were often obliged to feed on berries, roots, and the stalks of green maize; at the same time they were harrassed without intermission by large parties of Mexicans, who attacked them on all sides. On the sixth day they reached Otum-

Retreat of Cortez.

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ba, not far from the road between Mexico and Tlascala. Early next morning when they began to advance, flying parties of the enemy still hung upon their rear; and amidst the insults with which they accompanied their hostilities, Donna Marina remarked, that they often exclaimed with exultation, "Go on, robbers; go to the place where you shall quickly meet the vengeance due to your crimes." The meaning of this threat the Spaniards did not comprehend, until they reached the summit of an eminence before them. There a spacious valley opened to their view, covered with a vast army as far as the eye could reach.

The battle of Otumba.

The Mexicans, whilst with one body of their troops they harrassed the Spaniards in their retreat, had assembled their principal force on the other side of the lake; and marching along the road which led directly to Tlascala, posted it in the plain of Otumba, through which they knew Cortez must pass. At the sight of this incredible multitude, which they could survey at once from the rising ground, the Spaniards were astonished, and even the boldest amongst them began to despair. But Cortez, without allowing their fears time to operate, after warning them briefly that no alternative remained but to conquer or to perish, led them instantly to the charge. The Mexicans waited their approach with unusual fortitude; yet such was the superiority of the Spanish discipline and arms, that the impression of this small body was irresistible; and whichever way its force was directed, it penetrated and dispersed the most numerous battallions. But whilst these gave way in one quarter, new combatants advanced from another; and the Spaniards, though successful in every attack, were ready to sink under these repeated efforts, without seeing any end to their toil, or any hope of victory. At that time Cortez observed the great standard of the empire, which was carried before the Mexican general, advancing; and fortunately recollecting to have heard, that on the fate of it depended the event of every battle, he assembled a few of his bravest officers, whose horses were still capable of service, and placing himself at their head, pushed towards the standard with such impetuosity that he bore down every thing before him. A chosen body of nobles, who guarded the standard, made some resistance, but were soon broken. Cortez, with a stroke of his lance, wounded the Mexican general, and threw him to the ground; and one of his followers alighting, put an end to his life, and laid hold of the imperial standard. The moment that their leader fell, and the standard, towards which all directed their eyes, had disappeared, an universal panic struck the Mexicans; and, as if the bond which held them together had been dissolved, every ensign was lowered, and each soldier throwing away his weapons, fled with precipitation to the mountains. The Spaniards, unable to pursue them far, returned to collect the spoils of the field; and these were so valuable as to afford some compensation for the wealth which they had lost in Mexico; for in the enemy's army were most of their principal warriors dressed out in their richest ornaments, as if they had been marching to assured victory.

Measures adopted by Cortez.

The day after this important action, which was fought on the 8th of July 1520, the Spaniards entered the Tlascalan territories, where they were received with the most cordial friendship. Cortez endeavoured to avail himself of this disposition as much as possible; for which purpose he distributed amongst them the rich spoils taken at Otumba with such a liberal hand, that he made himself sure of obtaining from the republic whatever he should desire. He drew a small supply of ammunition, and two or three field-pieces, from his stores at Vera Cruz. He despatched an officer with four ships of Narvaez's fleet to Hispaniola and Jamaica, to engage adventurers, and to purchase horses, gunpowder, and other military stores. And as he knew that it would be in vain to attempt the reduction of Mexico, unless he could secure the command of the lake, he gave orders to prepare, in the mountains of Tlascala, materials for building twelve brigantines, so that they might be carried thither in pieces, ready to be put together, and launched when he stood in need of their service. But, in the meantime, his soldiers, alarmed at the thoughts of being exposed to such calamities a second time, presented a remonstrance to their general, in which they represented the imprudence of attacking a powerful empire with his shattered forces, and formally required him to return back to Cuba. All the eloquence of Cortez could now only prevail with them to delay their departure for some time, when he promised to dismiss such as should desire it. However, this was only a pretence; for Cortez in fact, had the conquest of Mexico as much at heart as ever. Without giving his soldiers an opportunity of caballing, therefore, he daily employed them against the people of the neighbouring provinces, who had cut off some detachments of Spaniards during his misfortunes at Mexico; and as he was constantly attended with success, his men soon resumed their wonted sense of superiority.

Cortez receives an unexpected reinforcement.

But all the efforts of Cortez could have been of little avail, had he not unexpectedly obtained a reinforcement of Spanish soldiers. These belonged to an armament fitted out by Francisco de Garay, governor of Jamaica, who had long aimed at dividing with Cortez the glory and the gain of annexing the empire of Mexico to the crown of Castille. They had, however, unadvisedly made their attempt on the northern provinces, where the country was poor and the inhabitants fierce and warlike; so that, after a succession of disasters, they were now obliged to venture into Vera Cruz, and cast themselves upon the mercy of their countrymen; and here they also were soon persuaded to throw off their allegiance to their master, and to enlist with Cortez. About the same time a ship arrived from Spain, freighted by some private adventurers, with military stores; and the cargo was eagerly purchased by Cortez, whilst the crew, following the example of the rest, joined him at Tlascala. From these various quarters, the army of Cortez was reinforced with one hundred and eighty men and twenty horses, by which means he was enabled to dismiss such of the soldiers of Narvaez as were most troublesome and discontented; after the departure of whom he still mustered upwards of five hundred infantry, of whom eighty were armed with muskets or cross-bows, forty horseman, and nine pieces of artillery. At the head of these, with ten thousand Tlascalans and other friendly Indians, he began his march towards Mexico, on the 28th of December, six months after his fatal retreat from that city.

Second advance on Mexico.

As soon as Cortez entered the enemy's territories, he discovered various preparations to obstruct his progress. But his troops forced their way with little difficulty, and took possession of Tezcuco, the second city of the empire, situated upon the banks of the lake, about twenty miles from Mexico. Here he determined to establish his head quarters, as the most proper station for launching his brigantines, as well as for making his approaches to the capital. In order to render his residence there more secure, he deposed the cacique or chief, who was at the head of that community, and substituted in his stead a person whom a faction of the nobles pointed out as the right heir of that dignity. As the construction of the brigantines advanced slowly under the unskilful hands of soldiers and Indians, whom Cortez was obliged to employ in assisting three or four carpenters who happened to be in his service, and as he had not yet received the reinforcement which he expected from Hispaniola, he was not in a condition to turn his arms directly against the capital. Three months elapsed before the materials for constructing the brigantines were finished, and before he heard any thing respecting the success of his negotiation in Hispaniola. This, however, was not a season of inaction to Cortez. He attacked successively several of the towns situated around the lake; and although

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all the Mexican power was exerted to obstruct his operations, he either compelled them to submit to the Spanish crown, or reduced them to ruins. Other towns he endeavoured to conciliate by more gentle means; and though he could not hold any intercourse with the inhabitants except by the intervention of interpreters, yet, under all the disadvantages of that tedious and imperfect mode of communication, he had acquired such a thorough knowledge of the state of the country, as well as of the dispositions of the people, that he conducted his negotiations and intrigues with astonishing dexterity and success. Most of the cities adjacent to Mexico were originally the capitals of small independent states; and some of them having been but lately annexed to the Mexican empire, still retained the remembrance of their ancient liberty, and bore with much impatience the rigorous yoke of their new masters. Cortez having early observed symptoms of disaffection, availed himself of this knowledge to gain their confidence and friendship. By offering to deliver them from the dominion of the Mexicans, and by liberal promises of more indulgent treatment if they should unite with him against their oppressors, he prevailed on the people of several considerable districts, not only to acknowledge the king of Castille as their sovereign, but to supply the Spanish camp with provisions, and to strengthen his army with auxiliary troops. On the first appearance of disaffection, Guatimozin exerted himself to suppress it; but, notwithstanding all his efforts the spirit continued to spread, and the Spaniards gradually acquired new allies.

Conspiracy against Cortez.

Whilst bythese various methods, Cortez was gradually circumscribing the Mexican power within such narrow limits that his prospect of overturning it seemed neither to be uncertain nor remote, all his schemes were well nigh defeated by a conspiracy against his own person, and which was discovered only a short time before it was to have been executed. Though many were concerned, Cortez did not think proper to punish any more than the principal ringleader, whom he caused immediately to be hanged; and then, without allowing them leisure to ruminate on what had happened, and as the most effectual means of preventing the return of a mutinous spirit, he determined to call forth his troops immediately to action. Fortunately a proper occasion for this soon occurred, without his seeming to court it. He received intelligence, that the materials for building the brigantines were at length completely finished, and waited only for a body of Spaniards to conduct them to Tezcuco. The command of this convoy, consisting of two hundred foot soldiers, fifteen horsemen, and two field pieces, he gave to Sandoval, who by the vigilance, activity, and courage, which he had manifested on every occasion, was growing daily in his confidence, and in the estimation of his fellow-soldiers. The Tlascalans furnished eight thousand Tamenes, an inferior order of men destined for servile tasks, to carry the materials on their shoulders, and appointed fifteen thousand warriors to accompany and defend them. Sandoval made the disposition for their progress with great propriety, placing the Tamenes in the centre, one body of warriors in the front, and another in the rear, with considerable parties to cover the flanks. To each of these he joined some Spaniards, not only to assist them in danger, but to accustom them to regularity and subordination. Parties of Mexicans frequently appeared hovering around them on the high grounds; but perceiving no prospect of success in attacking an enemy continually on his guard, and prepared to receive them, they did not venture to molest him; and Sandoval had the glory of conducting safely to Tezcuco a convoy upon which the success of the future operations of his countrymen depended.

Mexico besieged.

Cortez determined to attack the city from three different quarters; from Tezcuco on the east side of the lake, from Tacuba on the west, and from Cuayocan towards the south. These towns were situated on the principal causeways which led to the capital, and were intended for their defence. He appointed Sandoval to command in the first, Pedro de Alvarado in the second, and Christoval de Olid in the third; allotting to each a numerous body of Indian auxiliaries, together with an equal division of Spaniards, who, by the junction of the troops which had arrived from Hispaniola, amounted now to eighty-six horsemen, and eight hundred and eighteen foot soldiers, of whom one hundred and eighteen were armed with muskets or cross-bows. Their train of artillery consisted of three battering cannon, and fifteen field-pieces. He reserved for himself, as the station of greatest importance and danger, the conduct of the brigantines, each armed with one of his small cannon, and manned with twenty-five Spaniards. As Alvarado and Olid proceeded towards the posts assigned them, they broke down the aqueducts which the ingenuity of the Mexicans had erected for conveying water into the capital. Alvarado and Olid found the towns, of which they were ordered to take possession, deserted by their inhabitants, who had fled for safety to the capital, where Guatimozin had collected the principal force of his empire. The first effort made by the Mexicans was to destroy the fleet of brigantines, the fatal effects of which they foresaw and dreaded. Although the brigantines, after all the labour and merit of Cortez in forming them, were of inconsiderable bulk, rudely constructed, and manned chiefly with landsmen, scarcely possessed of skill sufficient to conduct them, they must have been objects of terror to a people unacquainted with any navigation but that of their lake, and possessed of no vessel larger than a canoe. Necessity, however, urged Guatimozin to hazard the attack; and hoping to supply by numbers what he wanted in force, he assembled such a multitude of canoes as covered the face of the lake. These frail skiffs rowed on boldly to the charge, whilst the brigantines, retarded by a dead calm, could scarcely advance to meet them. But as the enemy drew near, a breeze suddenly sprung up; in a moment the sails were spread, and the brigantines with irresistible impetuosity broke through their feeble opponents, overset many canoes, and dissipated the whole armament. From that time Cortez remained master of the lake; and the brigantines not only preserved a communication between the Spaniards in their different stations, although at a considerable distance from each other, but were employed to cover the causeways on each side, and keep off the canoes, when they attempted to annoy the troops as they advanced towards the city. He formed the brigantines into three divisions, allotting one to each station, with orders to second the operations of the officer who commanded there. From all the three stations he pushed on the attack against the city with equal vigour, but in a manner very different from that in which sieges are conducted in regular war. Each morning his troops assaulted the barricades which the enemy had erected on the causeways, forced their way over the trenches which they had dug, and through the canals where the bridges were broken down, and endeavoured to penetrate into the heart of the city, in hopes of obtaining some decisive advantage, which might force the enemy to surrender, and terminate the war at once; but when the obstinate valour of the Mexicans had rendered the efforts of the day ineffectual, the Spaniards retired in the evening to their former quarters. Thus their toil and danger were, in some measure, continually renewed; the Mexicans repairing in the night what the Spaniards had destroyed during the day, and recovering the posts from which they had been driven. But necessity prescribed this slow and untoward mode of operation. The number of his troops was in fact so small, that Cortez durst not, with a handful of men, attempt to make a lodgment in a city where he might be surrounded and annoyed by a multitude of enemies. The remembrance of what he had already suffered by the ill-judged confidence with which he had ventured into such a dangerous situa-

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tion, was still fresh in his memory. The Spaniards, exhausted with fatigue, were unable to guard the various posts which they had daily gained; and although their camp was filled with Indian auxiliaries, they durst not devolve this charge upon them, because they were so little accustomed to discipline, that no confidence whatever could be placed in their vigilance. Besides, Cortez was extremely solicitous to preserve the city as much as possible from destruction, partly because he had destined it to be the capital of his conquests, and partly because he wished that it might remain as a monument of his glory. From these considerations, he adhered obstinately for a month to the system which he had adopted. The Mexicans, in their own defence, displayed a valour which was hardly inferior to that with which the Spaniards attacked them. On land, on water, by day and by night, one furious conflict succeeded to another. Several Spaniards were killed, more were wounded, and all were ready to sink under the toils of unintermitting service, which were rendered more intolerable by the injuries of the season, the periodical rains having by this time set in with their usual violence.

Difficulties of the enterprise.

Astonished and disconcerted with the length and difficulties of the siege, Cortez determined to make one great effort to get possession of the city before he relinquished the plan which he had hitherto followed. With this view he sent instructions to Alvarado and Sandoval to advance with their divisions to a general assault, and took the command in person of that which was posted on the causeway of Cuyocan. Animated by his presence, and the expectation of some decisive event, the Spaniards pushed forward with irresistible impetuosity; broke through one barricade after another; forced their way over the ditches and canals, and having entered the city, gained ground incessantly, in spite of the multitude and ferocity of their opponents. Cortez, though delighted with the rapidity of his progress, did not forget that he might still find it necessary to retreat; and in order to secure it, appointed Julian de Alderete, a captain of note in the troops which he had received from Hispaniola, to fill up the canals and gaps in the causeway as the main body advanced. But that officer deeming it inglorious to be thus employed, whilst his companions were in the heat of action and in the career of victory, neglected the important charge committed to him, and hurried on inconsiderately to mingle with the combatants. The Mexicans, whose military attention and skill were daily improving, no sooner observed this, than they carried an account of it to their monarch. Guatimozin instantly discerned the consequences of the error which the Spaniards had committed, and, with admirable presence of mind, prepared to take advantage of it. He commanded the troops posted in the front to slacken their efforts, in order to allure the Spaniards to push forward, whilst he despatched a large body of chosen warriors through different streets, some by land and others by water, towards the great breach in the causeway, which had been left open. On a signal given by him, the priests in the great temple struck the great drum consecrated to the god of war; and no sooner did the Mexicans hear its solemn sound, calculated to inspire them with enthusiastic ardour and contempt of death, than they rushed upon the enemy with frantic rage. The Spaniards, unable to resist men urged by religious fury as well as the hope of success, began to retire, at first leisurely, and with a good countenance, but as the enemy pressed on, and their own impatience to escape increased, the terror and confusion became general. When they arrived at the gap in the causeway, Spaniards and Tlascalans, horsemen and infantry, plunged in promiscuously, whilst the Mexicans rushed fiercely upon them from every side; their little canoes carrying them through shoals which the brigantines could not approach. In vain did Cortez attempt to stop and to rally his flying troops. Fear had rendered them regardless of his entreaties or commands. Finding all his endeavours to renew the combat fruitless, his next care was to save some of those who had thrown themselves into the water; but whilst thus employed, with more attention to their situation than to his own, six Mexican captains suddenly laid hold of him, and were hurrying him off in triumph; and although two of his officers rescued him at the expence of their own lives, he received several dangerous wounds before he could break loose. Above sixty Spaniards perished in the rout; and what rendered the disaster more afflicting, forty of these fell alive into the hands of an enemy never known to shew mercy to a captive. The approach of night, though it delivered the dejected Spaniards from the attacks of the enemy, ushered in, what was hardly less grievous, the noise of their barbarous triumph, and of the horrid festival with which they celebrated their victory. Every quarter of the city was illuminated; and the great temple shone with such splendour, that the Spaniards could plainly see the people in motion, and the priests busy in hastening the preparation for the death of the prisoners. Through the gloom they fancied that they discerned their companions by the whiteness of their skins, as they were stripped naked and compelled to dance before the image of the god to whom they were about to be offered. They heard the shrieks of those who were sacrificed, and thought they could distinguish each unhappy victim by the well-known sound of his voice. Imagination added to what they really saw or heard, and augmented its horror. The most unfeeling melted into tears of compassion, and the stoutest heart trembled at the dreadful spectacle which they beheld.

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Critical state of affairs.

Cortez, who, besides all that he felt in common with his soldiers, was oppressed with the additional load of anxious reflections natural to a general on such an unexpected calamity, could not like them relieve his mind by giving vent to its anguish. He was obliged to assume an air of tranquillity, in order to revive the spirits and sustain the hopes of his followers. The juncture, indeed, required an extraordinary exertion of fortitude; for the Mexicans, elated with their victory, sallied out next morning to attack him in his quarters. But they did not rely on the efforts of their own arms alone. They sent the heads of the Spaniards whom they had sacrificed to the leading men in the adjacent provinces, and assured them that the god of war, appeased by the blood of their invaders, which had been shed so plentifully on his altars, had declared with an audible voice, that in eight days time these hated enemies should be finally destroyed, and peace and prosperity re-established in the empire. A prediction, uttered with such confidence, gained universal credit amongst a people prone to superstition. The zeal of the provinces which had already declared against the Spaniards augmented, and several which had hitherto remained inactive now took arms to execute the decrees of the gods. The Indian auxiliaries who had joined Cortez, accustomed to venerate the same deities with the Mexicans, and to receive the responses of their priests with the same implicit faith, abandoned the Spaniards as a race of men devoted to destruction. Even the fidelity of the Tlascalans was shaken, and the Spanish troops were left almost alone in their stations. Cortez, finding that he had attempted in vain to dispel the superstitious fears of his confederates by argument, took advantage, from the imprudence of those who had framed the prophecy, in fixing its accomplishment so near at hand, to give them a striking demonstration of its falsity. He suspended all military operations during the period marked out by the oracle. Under cover of the brigantines, which kept the enemy at a distance, his troops lay in safety, and the fatal term expired without any disaster. His allies, ashamed of their own credulity, now returned to their station. Other tribes, judging that the gods, who had deceived the Mexicans, must have decreed finally to withdraw their protection from that nation, joined his standard; and such was the levity of a simple people, moved by every slight

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impression, that in a short time after such a general defection of his confederates, Cortez saw himself, if we may believe his own account, at the head of 150,000 Indians.

Cortez adopts a more cautious method of attack.

Even with such a numerous army, he found it necessary to adopt a new and more cautious system of operations. Instead of renewing his attempts to become master of the city at once, by such bold but dangerous efforts of valour as he had already tried, he made his advances gradually, and with every possible precaution. As the Spaniards pushed forward, the Indians regularly repaired the causeways behind them. As soon as they got possession of any part of the town, the houses were instantly levelled with the ground. Day by day, the Mexicans, forced to retire as their enemies gained ground, were hemmed in within more narrow limits. Guatimozin, though unable to stop the career of the enemy, continued to defend his capital with the most obstinate resolution, and to dispute every inch of ground. But the Spaniards, having not only varied their mode of attack, but changed the weapons with which they fought, were again armed with the long Chinantlan spears, which they had employed with such success against Narvaez; and, by the firm order in which this enabled them to range themselves, they repelled, with little danger, the loose assault of the Mexicans, great numbers of whom fell in the conflicts which they renewed every day. Whilst war wasted without, famine began to consume them within the city. The Spanish brigantines, having the entire command of the lake, rendered it impossible to receive any supply of provisions by water; and the vast number of his Indian auxiliaries enabled Cortez to shut up the avenues to the city by land. The stores which Guatimozin had laid up were exhausted by the multitudes which crowded into the capital to defend their sovereign and the temples of their gods. Not only the people, but persons of the highest rank, felt the utmost distresses of want; and these sufferings brought on infectious and mortal distempers, the last calamity which visits besieged cities, and fills up the measure of their woes.

Refusal of Guatimozin to submit on any terms.

But, under the pressure of so many and such various evils, the spirit of Guatimozin remained firm and unsubdued. He rejected with scorn every overture of peace from Cortez; and, disdaining the idea of submitting to the oppressors of his country, determined not to survive its ruin. The Spaniards continued their progress. At length all the three divisions penetrated into the great square in the centre of the city, and made a secure lodgment there. Three-fourths of the city were now reduced, and laid in ruins; and the remaining quarter was so closely pressed, that it could not long withstand assailants who attacked it from their new position with superior advantage, and more assured expectation of success. The Mexican nobles, solicitous to save the life of a monarch whom they revered, prevailed on Guatimozin to retire from a place where resistance was now vain, that he might rouse the more distant provinces of the empire to arms, and maintain there a more successful struggle with the public enemy. In order to facilitate the execution of this measure, they endeavoured to amuse Cortez with overtures of submission, that, whilst his attention was employed in adjusting the articles of pacification, Guatimozin might escape unperceived. But they made this attempt upon a leader of too great sagacity and discernment to be deceived by their arts. Cortez suspecting their intention, appointed Sandoval, an officer on whose vigilance he could rely, to take the command of the brigantines, with strict injunctions to watch every motion of the enemy. Sandoval, attentive to the charge, having observed some large canoes crowded with people rowing along the lake with extraordinary rapidity, instantly gave the signal to chase. Gracia Holguin, who commanded the fastest-sailing brigantine, soon overtook them, and was preparing to fire on the foremost canoe, which seemed to carry some person whom all the rest followed and obeyed. At once the rowers dropt their oars, and all on board, throwing down their arms, conjured him with cries and tears to forbear, as the emperor was there. Holguin eagerly seized his prize; and Guatimozin, with a dignified composure, gave himself up into his hands, requesting only that no insult might be offered to the empress or his children. When conducted to Cortez, he exhibited neither the sullen fierceness of a barbarian, nor the crouching dejection of a supplicant. Addressing himself to the Spanish general, "I have done," said he, "what became a monarch. I have defended my people to the last extremity. Nothing now remains but to die. Take this dagger," laying his hand on one which Cortez wore; "plant it in my breast, and put an end to a life which can no longer be of use."

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Submission of Mexico.

As soon as the fate of their sovereign was known, the resistance of the Mexicans ceased; and Cortez took possession of that small part of the capital which yet remained undestroyed. Thus terminated the siege of Mexico, the most memorable event in the conquest of America. It continued seventy-five days, hardly one of which passed without some extraordinary effort of one party in the attack, or of the other in the defence of a city, upon the fate of which both knew that the fortune of the empire depended. As the struggle here was more obstinate, it was likewise more equal, than any between the inhabitants of the Old and the New World. The great abilities of Guatimozin, the number of his troops, and the peculiar situation of his capital, so far counterbalanced the superiority of the Spaniards in arms and discipline, that they must have relinquished the enterprise, if they had trusted for success to themselves alone. But Mexico was overturned by the jealousy of neighbours who dreaded its power, and by the revolt of subjects impatient to shake off its yoke. By their effectual aid, Cortez was enabled to accomplish that which without such support, he would hardly have ventured to attempt. How much soever this account of the reduction of Mexico may detract, on the one hand, from the marvellous relations of some Spanish writers, by ascribing that to simple and obvious causes which they attribute to the romantic valour of their countrymen, it adds, on the other, to the merit and abilities of Cortez, who, under every disadvantage, acquired such an ascendancy over unknown nations, as to render them instrumental in carrying his scheme into execution.

The exultation of the Spaniards upon accomplishing this arduous enterprise, was excessive. But their rejoicing was quickly damped by the disappointment of those hopes which had animated them amidst so many hardships and dangers. Instead of the inexhaustible wealth which they expected upon becoming masters of Montezuma's treasures, and the ornaments of so many temples, their rapacity could collect only an inconsiderable booty amidst ruins and desolation.[1] Guatimozin, aware of his impending fate, had ordered what remained of the riches amassed by his ancestors to be thrown into the lake; and the Indian auxiliaries, whilst the Spaniards were engaged in conflict with the enemy, had carried off the most valuable part of the spoil. The sum to be divided amongst the conquerors was so small, that many of them disdained to accept of the pittance which fell to their share, and all murmured; some against Cortez and his confidants, whom they suspected of having secretly appropriated to their own use a large portion of the riches which should have been brought into the common stock; others against Guatimozin, whom they accused of obstinacy, in refusing to discover the place where he had hidden his treasure.

Guatimozin tortured

Arguments, entreaties, and promises were employed in order to soothe them; but with so little effect, that Cortez,

[1] The gold and silver, according to Cortez, amounted only to 120,000 pesos, a sum far inferior to that which the Spaniards had formerly divided in Mexico.

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from solicitude to check this growing spirit of discontent, consented to a deed which has stained the glory of all his great actions. Without regarding the former dignity of Guatimozin, or feeling any reverence for those virtues which he had displayed, he subjected that unfortunate monarch, along with his chief favourite, to torture, in order to force from them a discovery of the royal treasures, which it was supposed they had concealed. Guatimozin bore whatever the refined cruelty of his tormentors could inflict, with the invincible fortitude of an American warrior. His fellow-sufferer, overcome by the violence of the anguish, turned a dejected eye towards his master, which seemed to implore his permission to reveal all that he knew. But the high-spirited prince, darting on him a look of authority mingled with scorn, checked his weakness, by asking, "Am I now reposing on a bed of flowers?" Overawed by the reproach, he persevered in his dutiful silence, and expired. Cortez, ashamed of a scene so horrid, rescued the royal victim from the hands of his torturers, and prolonged a life reserved for new indignities and sufferings.

The Spaniards become masters of the Mexican empire.

The fate of the capital, as both parties had foreseen, decided that of the empire. The provinces one after another submitted to the conquerors. Small detachments of Spaniards marching through them without interruption, penetrated, in different quarters, to the great Southern Ocean, which, according to the ideas of Columbus, they imagined would open a short and easy passage to the East Indies, and thus secure to the crown of Castille all the envied wealth of those fertile regions; and the active mind of Cortez began already to form plans for attempting this important discovery. In his subsequent schemes, however, he was disappointed; but from this time until the revolutionary spirit broke out in the New World, not long after the commencement of the present century, Mexico remained in the hands of the Spaniards.

II. HISTORY OF MEXICO FROM THE COMMENCEMENT OF THE REVOLUTION TO THE PRESENT TIME.

Revolt of the Hispano-American colonies.

For nearly three centuries after the conquest of Cortez, Mexico remained quietly subject to the Spanish yoke; but the internal tranquillity thus enjoyed ceased with the invasion of Old Spain by the armies of Napoleon. The humiliation of the mother country was the signal for revolt throughout all her colonial possessions; and commotions then took place which for years continued to agitate the country. But before proceeding to narrate the events which have terminated in the separation of Mexico from the mother country, it will be necessary briefly to review the system of colonial policy by which it was so long governed, and to point out the causes which ultimately led to the assertion of independence. It is to the complication of abuses, to which the old system gave rise, that we must mainly attribute those events which have changed the destiny of the New World.

Division and government of the Spanish American possessions.

The vast American possessions of Spain were divided into five captain-generalships, viz., Yucatan, Guatemala, Chili, Venezuela, and the island of Cuba; and four viceroyalties, viz., Mexico, Peru, Rio de la Plata, (Buenos Ayres), and New Granada. The government of each separate colony was vested in one of these great servants of the crown, who were all independent of each other. In Mexico the viceroy was endowed with the prerogatives of royalty, and considered as the *alter ego* of the king himself. He was commander-in-chief of the troops, and he regulated the military operations, and filled up all vacancies; it being understood that promotions made by him would receive the sanction of the king. He was assisted in this part of his duty by a council of war, as he was in all judicial questions by a fiscal, or legal adviser to whom the law of the case was referred. All sentences of every description bore his signature, nor was there any appeal from his decision. The only checks which interposed between him and despotic sovereignty were the *residencia*, or legal investigation of his conduct, to which the king might subject him on his return to Spain, a measure which was seldom or never enforced; and the *Audencia*, or the court of appeal in the last resort. This body possessed considerable power and influence. It had control over all other tribunals, ecclesiastical as well as civil, in every case where the value of the subject in litigation did not exceed ten thousand dollars. It likewise enjoyed the privilege of corresponding directly with the sovereign, and with the council of the Indies, a board at which the king was supposed constantly to preside in person, and whose sanction it was necessary to obtain before orders, decrees, or projects of reform, although emanating from the crown, could acquire the force of law. This board was created in 1511 by Ferdinand II., and remodelled by Charles V. in 1524, for the exclusive superintendence of the affairs of the colonies. The laws enacted by the last named monarch were in general wise and equitable, and framed in the spirit of humanity. It was decreed that the aborigines should be considered as freemen and vassals of the crown; and also that the discoverers, the settlers, and their posterity, including others "born in the country," were to be preferred in all appointments, civil and ecclesiastical. These laws, however, as we shall immediately see, proved a dead letter to the natives; for from the very first the government had pursued a course of policy diametrically the reverse of that which they guaranteed.

Audiencia.

The Audiencia was entirely composed of European Spaniards, who were forbidden to intermarry with creoles, (as were the viceroy and his children), or to engage in trade, or even to hold property in the country in which they resided. The privilege of directly corresponding with the Council of the Indies, might have rendered this body an efficient check upon the conduct of the viceroy, if the latter had not possessed such inordinate power. He was himself honorary president of the body, and had thus every opportunity of conciliating the members, and attaching them to his interests and those of the Europeans. As some compensation, they were entitled to assume the supreme power in the event of the viceroy's decease or removal, which they exercised until his successor was appointed. They also enjoyed various other privileges, which in a pecuniary point of view rendered their position highly advantageous. Indeed, the emoluments attached to the office of *oidor*, or member, were so considerable, that no small degree of influence, intrigue, and bribery was employed to obtain the situation. Three branches of the Audiencia were established in the provinces most remote from the capital, but these exercised no independent jurisdiction.

Municipal corporations.

Besides the boards already noticed, the municipal corporations, from their great possessions, had naturally a considerable share of influence; and that of the city of Mexico, containing a population of 140,000 inhabitants with immense estates, had a larger proportion than usually fell to the lot of other Spanish American cities. Those municipalities, called sometimes the *Cabildo*, sometimes the *Ayuntamiento*, and sometimes the *City*, were in their composition not unlike the ancient parliaments of France. Their members, called *regidors*, their president, the *corregidor*, and their executive officers, the *syndics*, were chosen from the people, and originally by the people; and although the institution was soon perverted, the people always looked up to it with respect, and regarded the members of the Cabildo as their natural protectors. Had the people been permitted to exercise their privilege without interference, the Ayuntamiento might have proved equivalent to an English House of Commons; but the right of election was rendered merely nominal by Spanish fraud or gold. The situations of alcalde and regidor were in fact put up to auction, and disposed of to the highest bidder, the

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purchaser having the power of relinquishing them in favour of relatives or friends. In some parts of the country they were even made use of as an inducement to people to enter themselves on the militia roll. Disgracefully as things were thus conducted, these functionaries uniformly proved the friends of the creoles; for they were connected with them by numerous ties, which the members of the Audiencia were prohibited from forming, and by a community of interests, which could not exist between the Europeans and any of the natives. Another important class of officials were the collectors of customs and revenue. These consisted of a host of officers, who were subordinate to the *Intendentes*, one of whom presided over a district, in which he was almost independent, for his appointment emanated from the council of the Indies, without the concurrence of the viceroy; and in all questions respecting the interests of the revenue he possessed very extensive powers.

State of the laws.

The *Recopilacion de las Leyes de las Indias*, or general collection of the laws of the Indies, was the name given to that chaotic mass of statutes by which the decisions of the tribunals were supposed to be determined. These statutes were originally merely decrees upon different subjects, emanating from the king or from the Council of the Indies; and being all bound up together, without regard to order or classification of any kind, they were generally unconnected, often contradictory, and almost always full of glaring inconsistencies. Nothing could have been conceived better calculated to embarrass the lawyer, and to defeat the ends of justice, than this farrago of legislative enactments. Indeed it was not long before the decrees *not* included in this heterogeneous budget of statutes outnumbered those which it contained; many of these, again, were annulled by others subsequently issued, so that it was scarcely possible to know which decrees were in force, and which had fallen into disuse or been suspended. It is quite obvious that from these causes, discrepancies in the royal orders were likely to occur frequently; and that in the general confusion, ample facilities were afforded to the delinquent of defeating the ends of justice, by sheltering himself under some forgotten or ambiguous decree. An appeal to judicial authority had thus in it all the uncertainty and hazard of a game of chance; and this was further increased by different professions and corporate bodies enjoying various special privileges or *fueros*. Each of these exempted the persons who chose to plead it, from the jurisdiction of the ordinary authorities, and made them amenable, in all civil and criminal causes, to the tribunal of the head of the body to which they belonged. It thus happened that the native American was generally the sufferer in cases in which his opponent was a European; for the difficulty of obtaining redress in any dispute was augmented by the circumstance of the latter enjoying a double or triple *fuero*, as a merchant, a government officer, a dignitary of the church, or at least as holding some rank in the militia.

Ecclesiastical establishments.

To complete the outline of that mighty fabric by which the authority of Spain in the New World was so long supported, it is necessary briefly to advert to ecclesiastical establishments. These were altogether independent of the see of Rome, and the Spanish sovereign was as effectually the head of the Hispano-American church as Henry VIII. made himself of that of England. No spiritual jurisdiction was allowed to interfere with the royal prerogative, so that the Pope could neither fulminate bulls nor hold any sort of intercourse with Spanish America, unless through the medium of the court of Madrid, and the Council of the Indies. As might have been expected under such circumstances, a traffic in bulls became an important branch of the royal revenue. The king bought of the holy see indulgences and dispensations of all kinds, and retailed them to his American subjects at an enormous profit. The business was managed with as much strictness and regularity as an ordinary commercial transaction, the monopoly of tobacco, for example; and so jealous was the king of his right, that the most severe penalties were not only enacted but enforced against ecclesiastics who dared to infringe the regulations. This traffic, which proved to be as lucrative as it was discreditable to both parties, was not carried on without some contentions between the courts of Madrid and Rome, the latter of which threatened to dissolve the partnership, for the Pontiff felt anxious to obtain a larger share than he actually possessed of so advantageous a concern; but after several ineffectual attempts to attain his object, he was compelled to relinquish the contest, and leave his royal partner in quiet possession of nearly the whole of the profits. The leading principle in the Spanish colonial system, was to represent power and authority, right and privilege, every thing in short, which an American enjoyed or could hope for of place or advancement, as all emanating from the king, the great fountain-head of honour and preferment. Had the Pope, therefore, in virtue of his sacred character, and independently of the Council of the Indies, held immediate intercourse with the Americans, who, being Catholics, were, like the inhabitants of other countries professing a similar faith, his spiritual subjects, it would have disturbed that unity of plan which it was the darling object of the Spaniards to maintain unbroken. Thus, not only the avarice but the policy of the mother country was concerned in excluding all interference, and hence the designs of the court of Rome were as suspiciously watched, as the attempts of the English or French to smuggle their manufactures into the country.

Evils of the Spanish colonial system.

Such is a general view of the colonial system of Spain; and when we consider that all the great offices of state, not excepting the vice-regal dignity itself, were open alike to Americans and Europeans, every subject of the crown being eligible, its defects, in theory at least, are scarcely so glaring as they are sometimes represented. The evils, many and grievous, consisted in the practice, and in the maintenance of a system of laws by which the colonies were sacrificed to the mother country. Nothing is so frequently or so strongly insisted upon in the *Recopilaciones*, as the equality to which we have just alluded; nothing was in practice so utterly lost sight of by the Spaniards. Every situation, from the highest to the lowest was bestowed upon Europeans; nor for many years previously to the revolution, was a single native preferred to any official post either in the church, the army, or the law. Indeed, the colonial offices were disposed of in Madrid to the highest bidder; and at one time the proceeds, like the traffic in bulls, formed a not inconsiderable item of the royal revenues. Of the fifty viceroys who governed Mexico from 1535 to 1808, only one was an American, and even he was born in Peru. The same spirit of self-aggrandisement and contempt for the natives, extended to the meanest offices in the gift of the crown; for even amongst the common clerks and other subordinates, an American was rarely to be met with. The manifesto published by the Congress of Buenos Ayres, places the condition to which the native population had been reduced, in a very strong light; and as the statements which are there made apply to Mexico and all the other Spanish settlements in America, it may be here proper to make a few extracts from this important document.

"Every thing," says the manifesto in question, "was disposed of on the part of Spain in America, to effect the degradation of her sons. It did not suit the policy of Spain that sages should rise up amongst us; fearful lest men of genius should remind them of advancing the condition of their country, and of improving the morals and excellent capacities with which its sons have been gifted by their Creator, it was her policy incessantly to diminish and depress our population, lest one day we should imagine aught against her domination, guarded by a force too contemptible for keeping in subjection regions so various and so extensive. Commerce was exclusively confined to herself, from a mean suspicion

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that opulence would make us proud, and render us capable of aspiring to free ourselves from so many vexations. The growth of industry was checked, in order that the means of escaping from our wretchedness and poverty might be denied us; and we were excluded from all participation in public employments, in order that the natives of the Peninsula might have entire influence over the country, so as to form the inclinations and habits necessary for retaining us in a state of dependence, that would permit us neither to think nor to act but in conformity to the modes dictated by the Spaniards.

"This system was acted upon with the utmost rigour by the viceroys. Each of them was invested with the authority of a vizier; their power was sufficient to annihilate all those who dared to displease them. However great the vexations they practised, we had to bear them with patience, whilst these were compared by their satellites and worshippers to the effects of the wrath of God. The complaints which were addressed to the throne were either lost in the distance of many thousand leagues over which they had to pass, or they were smothered in the offices at Madrid by the protectors of those who tyrannised over us. Not only was this system not softened, but there was no hope of its moderating in the course of time. We had no voice, direct nor indirect, in legislating for our country; this was done for us in Spain, without conceding to us the privilege of sending delegates or counsellors, to be present, and to state what would be suitable or otherwise, as is practised by the cities of Spain. Neither did we possess such influence in the government set over us, as might serve to attemper the severity of its administration. We knew that there was no remedy for us but to bear with patience; and that for him who could not resign himself to every abuse, death was considered as too light a punishment, for in such cases punishments have been invented of unparalleled cruelty, and revolting to every sentiment of humanity."

Literature.

In the passage that has just been cited, allusion is made to literature and commerce, both of which, as far as the natives were concerned, were rigorously interdicted. The power of Spain depended upon the ignorance of those over whom she ruled; and hence to have disseminated the blessings of education amongst the people, would have been to sap the very foundations of her authority. The consequence was, that almost every species of learning was not only discouraged but prohibited, and pains and penalties were annexed to the infringement of the laws relating to it. "It was forbidden," says the manifesto above quoted, "to teach us the liberal sciences; we were permitted to learn only the Latin grammar, the philosophy of the schools, and civil and ecclesiastical jurisprudence." The Inquisition was not only constituted the guardian of a doctrine which was studiously instilled into the minds of the natives, namely that all foreigners, such as English, French, Germans, and others, were heretics, with whom no Catholic could hold intercourse without contamination; but it also took special cognizance of the importation of books. All the ingenuity of this odious tribunal was exerted to check the introduction of works in the leaves of which a liberal sentiment might be supposed to lurk; and every vessel was accordingly subjected to the most searching examination. The works of Luther lay not under a stricter interdict than modern histories, and political writings; and even as late as the year 1811, the doctrine of the sovereignty of the people was, by a strange anomaly, denounced as a damnable heresy in Mexico, at the very moment that it was solemnly sanctioned by the Cortez in Spain. In a word, although certain studies that seemed calculated to do little or no harm were encouraged, the spirit of the system was to exclude information, to stifle enquiry, and to check the progress of intellectual improvement amongst the native population.

Commerce and industry.

But whilst ignorance was ranked amongst the virtues, some branches of industry were degraded into crimes. As the commercial restrictions, and the endless train of grievances, vexations, and abuses, of which these became the prolific source, generated that spirit of resistance which terminated in the overthrow of the Spanish power in America, we shall briefly enumerate some of those which were most obnoxious, and inimical to native industry and enterprise.

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Restrictions affecting the products of the soil.

The Americans were prohibited under severe penalties from raising flax, hemp, or saffron, and growing tobacco was a government monopoly. The cultivation of the olive, the mulbery, and the vine, was also frustrated by the same blind policy; and even the growth of the more precious articles, of what we term colonial produce, such as cacao, coffee, and indigo, was only tolerated under certain limitations, and in such quantities as the mother country might require annually to import. During M. Humboldt's residence in Mexico in 1802, the court of Madrid sent orders to the viceroy to root up all the vines in the northern provinces, because the merchants of the Spanish capital complained of a diminution in the consumption of their wines. Happily this order was not carried into execution; but that it should ever have been issued, shows the contempt in which the Spaniards held both the Americans and their property. Not only were they prohibited from appropriating to their use the vegetable productions which nature had bountifully scattered over their native hills and valleys; they were actually forbidden, to manufacture any thing which could be supplied by the mother country, and to the interests of a few maritime towns in Spain, the ministry unhesitatingly sacrificed the prosperity of a large portion of the New World. Had the traders taken in return those agricultural productions in which the colonies abounded, the grievance would have been ameliorated; but payment in specie was the grand object of the Spanish merchant. In conformity with the principle of concentrating all trade in the Peninsula, foreigners were entirely excluded from the colonial market. The natives were forbidden, upon pain of death, to hold commercial intercourse with them, and none were allowed to visit their shores. From time to time concessions were made in favour of a traffic with other nations; but these were not at all equal to the demands and the growing importance of the colonies.

Abuse of Licences.

We have already alluded to the sale of titles and distinctions; but the most lucrative branch of what deserves no better name than legal peculation, was the power of granting licences for the introduction of any article of foreign produce during a limited period. For these, enormous sums were paid by the leading commercial houses; and a share in the profits accruing from the speculation commenced with the viceroy, and extended to the meanest offices which swarmed with European hangers-on, all candidates for preferment, and waiting in expectation of realizing a fortune, in which they generally succeeded by means best known to themselves. It was in vain for the creoles to attempt bringing offenders to justice. Actuated by a spirit of clanship, the Europeans all clung together, one taking shelter behind another in an ascending scale up to the viceroy himself, who seems generally to have covered the long series of delinquents. But the exclusion of foreign vessels from the Mexican ports was not all that the rapacity of Spain laid claim to; that country also asserted a right to supreme dominion over the vast oceans which surrounded her American possessions; and this she attempted to vindicate wherever a superiority of maritime force enabled her to do so. Even ships in distress were by a royal ordinance ordered to be seized as prizes, and their crews thrown into prison. As late as the year 1790, a very remarkable instance of this occurred. A vessel belonging to the United States having lost her rudder, and being otherwise damaged by a storm, was compelled to touch at the island of Juan Fernandez to refit. The governor quietly allowed the Boston trader to be repaired and to depart without molestation; but the viceroy under whom he served warmly reprehended him for dereliction of duty, expressing in no

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measured terms his displeasure at the negligence of the governor, in allowing the vessel to leave the island without having even attempted to seize her. His astonishment, he said, was excited "at the governor of any of the king's islands being so ignorant as not to know that any foreign vessel sailing in the South Sea without a Spanish license was to be treated as an enemy's vessel, although the country to which she belonged might be at peace and amity with Spain." Notwithstanding all the efforts of Spain, however, manufactures did make some little progress in the course of the three centuries during which she wielded the destinies of Mexico and the whole of South America; and the exclusion of foreign vessels from her colonies gave rise to one of the most extraordinary systems of organised smuggling which the world ever witnessed. This was known under the name of the contraband or forced trade, and was carried on in armed vessels which often bade defiance to the coast blockades of Spain, and, fighting their way to the American ports, landed great quantities of European goods. This system of warlike commerce was conducted by the Dutch, English, French, and others; and not only was it the means of imparting to the Americans a taste for the luxuries of Europe, but latterly no small portion of the leaven of knowledge was infused into the inert mass of the population spread over the Spanish possessions.

Other evils of the Spanish colonial system.

Such was the colonial system of Spain, which on all hands is admitted to have been worse even than that of the Portuguese or of the Dutch; and such were the evils to which it gave rise. When, therefore, in connection with these evils we further consider that the civil, fiscal, and criminal administration was tyrannical, unjust, or partial; that exactions in the shape of taxes, duties, and tithes, were levied with unexampled severity; that amongst the taxes was one which has justly been called, "the horrible *alcavala*," and pressed heavily on all classes, being levied *in infinitum* on every transfer of goods; that nothing escaped tithes, and that every individual was compelled to purchase annually a certain number of the papal bulls, under a penalty of forfeiting various important advantages; that every stage of legal procedure was in the most corrupt and deplorable state, and that the administration of justice had scarcely any existence whatever; that imprisonment was the grand recipe for every malady; that in the most horrible dungeons, ill diet, filth, infectious diseases, and corporal punishment, including occasional torture, all combined to unhumanize the fettered victim; and, finally, that the Inquisition bound in chains of darkness the minds of all classes of the community from the viceroy downwards;—he would be a bold theorist who should venture to affirm that Spain did not deserve that fate which soon befel her possessions in the New World.

Events in Spain; their effect in America.

How long an indisposition upon the part of the creoles to assert their rights might have continued, had not the events of the year 1808 occurred, it is impossible to say; but it is generally admitted that the insurrection of Aranjuez which led to the dismissal of Godoy, Prince of the Peace, and to the abdication of Charles VI., gave the first shock to the royal authority in America. Authentic intelligence of the resignation of the Spanish monarch arrived in Mexico on the 15th of July 1808. The government of the country at this critical moment was in the hands of Don Jose Iturrigaray, who is universally described as a good and just old man, but who was apparently deficient in energy and decision of character. Uncertain what line of conduct to pursue, he assembled the Audiencia, and at the suggestion of that body published the intelligence contained in the Madrid Gazette, without note or comment. But however indifferent the officers of state were upon this occasion, the inhabitants of Mexico were thrown into a ferment of indignation. Crowds eagerly assembled in the squares and public walks, and threats of vengeance against France were mingled with strong expressions of adherence to the cause of the deposed monarch. The Cabildo immediately presented an address tending to stimulate the zeal of the viceroy, who in consequence declared his determination to preserve to the last his loyalty to his sovereign, and his fidelity to Spain. The municipality and the popular party profited by the wish of Iturrigaray to conciliate them, and accordingly demanded a solemn abjuration of France and her partizans, on the part of the authorities, and the immediate creation of a *junta* in imitation of the mother country, composed of representatives of the different corporations of the kingdom. This suggestion, though not unfavourably received by the viceroy was opposed by the Audiencia, who declared that it was contrary to the privileges both of the crown and of the Europeans. For several weeks disputes ran high between the two bodies; the Audiencia urging the necessity of submitting to the assembly of Seville, by virtue of official advices, from which the viceroy had proclaimed Ferdinand, whilst the municipality demanded representatives from the various corporations.

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Imprisonment and removal of the viceroy.

At length despatches arrived from the junta of Asturias, assembled at Oviedo, also claiming supreme authority in the name of Ferdinand. This event furnished strong grounds for the creoles pressing their claim to a share in the government; and the Audiencia, finding that the viceroy was inclined to favour their opponents, (for it would appear that he had not formally acknowledged the authority of either of the peninsular juntas), determined to arrest and depose him, regarding his project as calculated to prove fatal to their interests. Accordingly a band of about two hundred and fifty Europeans, principally merchants, having been secretly organised, they proceeded at midnight on the 15th of September 1808, to the palace of the viceroy, seized him together with his wife and family, and conveyed all of them to prison. The Audiencia were well aware that this extreme measure would be resented by the people and the municipality, with whom Iturrigaray was popular; and to prevent any movement upon the part of the Mexicans, they assigned as the cause a suspicion of *heresy;* whilst to the better informed they attempted to justify their conduct by one of the laws of the code of the Indies, which provides, that in cases where the viceroy shall have exceeded his powers, the Audiencia has a right to interfere for the safety of the country. For the time their plans proved completely successful. Iturrigaray, after remaining a short time in the dungeons of the Inquisition, was conveyed to Vera Cruz, and sent a prisoner to Cadiz charged with a crime different from those already mentioned. The Audiencia well knew that under existing circumstances neither of the charges which they had brought against him in Mexico would be sufficient to justify their proceedings in the eyes of their masters at home; that the one was false and the other ridiculous. Accordingly in the manifesto which they transmitted to Spain along with the captive viceroy, he was impeached with a design to establish himself upon an independent throne, and with having acted independently of the authority of the central junta. The accusation was successful. Without trial or examination he was incarcerated in one of the dungeons of the city, and after languishing there for three years he was liberated by a general amnesty, ruined in fortune, in health, and in reputation.

Feelings of the creoles. Proceedings of the Audiencia.

In the meanwhile the creoles of Mexico were not inclined to submit with indifference to such violent changes; the cause of Iturrigaray they identified with their own, and considered his removal as implying their exclusion from power. To repress feelings so dangerous to the stability of their authority, the Audiencia ordered juntas of public security to be formed, and armed bands of Spaniards to be organised, who, under the convenient denomination of *patriots*, kept rigorous watch over those were suspected of having a bias in favour of the deposed viceroy. Not a few influential members of the Cabildo, who had voted for a Mexican junta

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were arrested and either banished or otherwise disposed of. The vice-regal authority was for the time confided to the archbishop Lizana; but the mild and conciliatory policy of this prelate accorded little with the views of the Audiencia, who met the advances of the natives with insolent harshness, and maintained their exclusive right to represent the absent king, conduct which only served to increase the general irritation. The Cabildo of Mexico was told by the Audiencia in answer to some remonstrance in favour of the viceroy "that it possessed no authority, except over the leperos (lazzaroni) of the capital;" and it was a favourite maxim with the oidor Bateller, one of the chief promoters of Iturrigaray's seizure, "that whilst a Manchego mule, or a Castilian cobler, remained in the peninsula, he had a right to govern the Americas." He was not alone in the expression of such outrageous sentiments. They were everywhere re-echoed by the Spaniards, who eagerly formed themselves into "patriotic associations" for the protection of what they called their rights, and armed themselves against the natives, whose excited feelings such proceedings were not likely to allay. In the year 1809 the archbishop was replaced by the Audiencia to whom the central junta transferred the reins of government; whilst the violent and contemptuous conduct of this body only served to bring matters more speedily to a crisis. A general feeling of hostility towards the Spaniards spread throughout the country, and as early as May 1809, attempts were made to concert insurrectionary movements, but these were crushed in embryo by the arrest of those principally concerned in them. This check, however, did not materially retard the onward movement of the country. A hatred of their oppressors had long been accumulating in the minds of the Mexicans, and discontent had become too general to be thus repressed. Although subdued in one part it broke out with more violence in another, like the volcanic eruptions of their native mountains. The scene of commotion alone was changed from the province of Michoacan to that of Guanajuato, where the famous Curate Hidalgo was destined first to raise the standard of revolt, and call forth the long subdued energies of his countrymen.[1]

Standard of independence raised by Hidalgo

Don Miguel Hidalgo y Costilla was a man of considerable natural talents, learned, active, intelligent, and, above all, in a high degree enthusiastic and enterprising. After distinguishing himself at the university of Valladolid, he was appointed rector of the little town of Dolores, in the province of Guanajuato. Here he encouraged manufactures amongst his parishioners, and also introduced the cultivation of the silk worm and the vine; but a special order from the capital prohibiting the making of wine, rendered the numerous vineyards which he had planted useless, and thus added a private cause of discontent to the long list of grievances which he shared in common with his countrymen. He paid much attention to the education of those under his care; and from the extreme devotion which he displayed towards the virgin of Guadalupe, he was held in great veneration by the inhabitants, over whom he consequently possessed almost unbounded influence. To form a party willing to embark in the enterprise which he meditated was therefore no very difficult task; for not only were his countrymen prepared for it beforehand, but the example of a man of his character and authority was irresistible. He took so little precaution to conceal his projects, that they were discovered before being fully matured, and orders were issued to arrest him, along with Alende, Aldama, and Abasolo, three creole officers whom he had seduced from their allegiance to Spain. This premature disclosure, however, only served to hasten the execution of his plan; and having secured the co-operation of several of his parishioners, on the morning of the 16th September 1810, the standard of revolt and independence was publicly unfurled. Seven Europeans, resident in Dolores, became the first victims of the revolutionary movement. They were thrown into prison, and their property seized and distributed amongst Hidalgo's followers. The news of this first exploit spread throughout the country with the rapidity of lightning, and was every where hailed as a propitious omen. His force increased so suddenly, that on the 18th, he found himself in possession of two towns, each containing sixteen thousand inhabitants, in both of which places the confiscated property of the Europeans enabled him to reward his partizans as well as to add to their numbers.

Capture of Guanajuato.

His next object was Guanajuato, the capital of the province, and also the emporium of the Spanish treasures in that part of the country. The town contained about seventy-five thousand inhabitants, who were governed by a magistrate of a decided and active character, and one highly respected for his integrity and benevolence, so that it became necessary for Hidalgo to take every precaution that the number of his troops should be equal to the enterprise which he contemplated. On the 28th of September, Abasolo was despatched with a letter to the intendant, announcing that Hidalgo had been elected "captain-general of America," and that the independence of Mexico was proclaimed; at the same time offering the Spaniards terms of capitulation, according to which their persons were to be respected. These were refused; and Hidalgo's troops, now amounting to about twenty thousand but indifferently armed, advanced to the attack. Strong symptoms of disaffection having been evinced by the lower classes in the town, the intendant could not undertake the defence of the whole of it from apprehension of treachery; so, with all the Europeans, he fortified himself in the public granary, whither he also conveyed the gold, silver, and other valuable property contained in the royal treasury. Little opposition was offered to the entrance of Hidalgo's troops, who were immediately joined by the whole population of the town, and carried all before them. The granary continued for some time to hold out, and the musketry did terrible execution amongst the crowds with which the streets were filled. But the death of the intendant relaxed the vigour of his followers. The great gate was forced, and the besieged, giving up resistance as hopeless, surrendered. Nothing could surpass the ferocity of the Indians, or the excesses which they committed. The town was given up to pillage; the Europeans were butchered without mercy; their property was eagerly seized; and before next morning there

[1] By some writers, the general discontent, and subsequent revolt, has been ascribed to the operation of other causes than those assigned in the text, namely, to a detestation of the French, and a determination to adhere to the Spanish monarch in every change of fortune. The interests of Spain and of its ex-king were totally distinct; for the former being conquered by Napoleon would of course be placed under a Corsican dynasty, to the exclusion of the family of the latter, in which case Mexico, being a colony of old Spain, would change masters and virtually become a colony of France. It has been assumed that the creoles suspected the Audiencia of being indifferent about who governed Spain, provided they ruled Mexico. These suspicions, it is said, were strengthened when intelligence arrived that the vice-regal power had been transferred to General Venegas, whom the Mexicans regarded as a traitor; and that the regency had expressed their approbation of the conduct of those who had deposed Iturrigaray, and had resolved to reward them with decorations and appointments. This appeared to the Mexicans decisive evidence of a design on the part of the regency and of their new viceroy, to annex Mexico to the fate of Spain, under a new ruler, to rid themselves of their old sovereign. The disasters which overwhelmed the Spanish cause in the peninsula were attributed to treachery, for the Spaniards had studiously instilled into the minds of the Americans so exalted an idea of the military prowess of their countrymen, that their subjugation by France could be accounted for in no other manner. Hence, it is concluded, sprung popular discontent, local eruptions, and finally a general insurrection. Now, without attaching much importance to this view of the case, it may, to a limited extent, be founded on truth, and discrepancies may be reconciled by supposing that the insurgents were actuated by various motives.

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was not left standing a single house which had belonged to a Spaniard. The sacking of the city continued for three days, and the plunderers were loaded with spoil. An enormous quantity of money and other treasure was found in the alhondiga or granary to which the inhabitants had transported their most valuable effects. It is generally estimated at five millions of dollars, the possession of which entirely changed the aspect of Hidalgo's enterprise, and gave it an importance in the eyes of the country which did not before belong to it. During his stay at Guanajuata, he established a sort of government, a mint with all the apurtenances for coining money, and a foundry for casting cannon, employing for the purpose the bells which had been found in the houses of the Europeans.

Proceedings of the new viceroy.

The intelligence of the fall of Guanajuato, whilst it gave celebrity to the name of Hidalgo, created great consternation amongst the Spaniards of the capital, who were but little prepared for such a display of energy and warlike prowess upon the part of the natives. The new viceroy, however, Don Francisco Xavier Venegas, although misled at first by representations of the cowardice of the Mexicans, soon perceived the true state of affairs, and displayed such judgment and firmness in his measures, that the creoles were compelled to repress their feelings of exultation, and public tranquillity remained undisturbed in the capital. Upon this, as a central point, he ordered the troops stationed in different parts of the country to be concentrated; and the command of one of the best regiments he confided to the Conde de la Cadena, a Mexican by birth. Don Felix Maria Calleja, who headed a brigade of troops stationed at San Luis Potosi, was also intrusted with a command, and ordered to pursue Hidalgo. Nor was the superstition of the people overlooked; for some doubts having arisen with respect to the justice of the sentence of excommunication which had been pronounced against the leader of the insurgents, it was confirmed by Lizana and by the Inquisition, who likewise declared that the same penalty should extend to all who dared to call in question its validity in future. In one respect only did the viceroy fail to evince his usual sagacity, namely, in distributing rewards amongst those individuals who were most active in deposing Iturrigaray. We have already alluded to the high estimation in which this functionary was held by the Mexicans, and hence a display of generosity towards his enemies was at once an open justification of their conduct, and an insult offered to those who had regarded his cause as identical with their own.

Advance of Hidalgo towards the capital.

After remaining at Guanajuato until the 10th of October, Hidalgo, at the head of his army, advanced upon Valladolid, which being abandoned by the Spaniards, was quietly taken possession of on the 17th of the same month. Here he was joined by some royal troops, and also by Don Jose Maria Morelos, curate of Nucupetaro, a very distinguished character, whose career we shall afterwards have occasion to trace. The army of Hidalgo was now about sixty thousand strong, a force which he considered as sufficient to conquer the capital, and thus, by one decisive blow, to terminate the revolutionary struggle. He accordingly left Valladolid on the 19th, and on the 28th arrived at Tolluco, a town within twelve leagues of the metropolis. An attempt was made to stop his further advance, by a corps of observation under the command of colonel Truxillo, assisted by Don Augustin Iturbide, then a lieutenant in the service of Spain. After a sanguinary contest, in which all the ordinary rules of war were set at defiance, the royalists were defeated, and compelled to fall back upon the capital. Venegas had succeeded in collecting about seven thousand men, who were stationed in the most advantageous manner for the defence of the city; but alarmed at the recent success and the near approach of the insurgents, he again drew upon the superstition of the people in support of the Spanish cause. An image of the Virgin, which the populace regarded with peculiar veneration, and which apparently, like the banner of Mahommed, was only exhibited upon critical or very solemn occasions, was brought from a little distance, and placed in the cathedral of Mexico. Thither the viceroy went in full uniform, and with all due pomp, to pay his respects to it; and after imploring the Virgin to take the government into her own hands, he wound up his appeal by laying his staff of command at the feet of her image.

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His retreat, and discomfiture at Aculco.

But the aid of the Virgin was not required in the present instance; for Hidalgo, after appearing before the city, to the astonishment of every one, and the delight of the Spaniards, withdrew his troops without risking an assault, and retreated upon Guanajuato. Various reasons have been assigned for his conduct upon this occasion, amongst which we may mention cowardice, and a desire to save the capital from destruction. But the fact is, that he found the viceroy better prepared than he had anticipated; the city being defended by batteries which Hidalgo foresaw he never would be able again to bring his half-armed and undisciplined band to face, so terrible had been the effects of the Spanish artillery in the previous conflict. Besides this, his ammunition was now nearly exhausted, and from some intercepted despatches of Calleja's, he learned that that officer was in full march upon the capital. Accordingly, to avoid the danger of being hemmed in between two fires, the insurgents commenced their retreat, and, on the 7th November, came in contact with the outposts of the royal army at Aculco. The surprise appears to have been mutual, neither party being aware of the proximity of the other. But a sanguinary action ensued, in which, from the superiority of their discipline and arms, the royal forces gained a complete victory. Indeed, the insurgents scarcely awaited the attack; for struck with the military evolutions and martial bearing of the royal army, which advanced upon them in five columns, they dispersed in confusion at their first approach, leaving ten thousand killed or wounded on the field of battle. But the commander and most of his officers effected their escape, and with as many fugitives as they could collect, effected a hasty retreat to Valladolid. Here Hidalgo remained a few days, and then proceeded to Guadalaxara, where he was received with the greatest pomp and enthusiasm. Soon after his arrival at this city, Hidalgo was joined by a small force under Alende.

Mutual atrocities.

After the disastrous battle of Aculco, the insurgent chief had taken the road to Guanajuato, with the intention of defending the town; but finding that his troops were incapable of opposing those of Calleja, he evacuated the place on the approach of the latter. It is universally admitted that the atrocities perpetrated in Guanajuato by the Spaniards were great; but they found some palliation for their conduct, in a circumstance which had occurred the very morning on which they entered the city. Between two and three hundred Europeans who had escaped the massacre which followed the capture of this place by Hidalgo, were left there by him as prisoners. After Alende's retreat the populace became furious, and in a paroxysm of rage flew to the fort where these unfortunate individuals were confined, and butchered them to a man. A similar atrocity was committed by Hidalgo, during his stay at Guadalaxara. Upon his arrival he had ordered all the Europeans to be thrown into confinement; and a vague rumour having arisen of a conspiracy amongst them, they were without trial or examination, and during the night, privately conveyed in small parties at a time, to lonely places in the neighbourhood of the city, and there despatched in cold blood. It is stated on good authority that between seven and eight hundred individuals perished in this diabolical manner. Thus the stern and inexorable spirit with which Hidalgo began the contest, was met by a spirit equally fierce and unrelenting on the part of the Spaniards, and gave to the revolution that sanguinary character which distinguished it throughout.

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At Guadalaxara Hidalgo proceeded with his usual activity to replenish his stores, recruit his forces, and bring cannon from San Blas, the principal Spanish arsenal on the western coast. The artillery which he thus with infinite labour collected, appeared to him so formidable, that with the aid of twelve hundred muskets, the total amount of his small arms, he thought he might be able to face Calleja and compel him to retreat. Flushed with this hope, he advanced to the bridge of Calderon, which is sixteen miles from Guadalaxara, and having fortified himself in a strong position, he awaited the approach of the royalists. On the 16th of January 1811, the two armies were once more in sight of each other, and on the following day a general action took place. After various attacks which the Mexicans repulsed with spirit, Calleja at last succeeded in carrying all their batteries; and the explosion of an ammunition waggon having thrown them into confusion, Hidalgo was forced to withdraw them from the field. The retreat was effected in good order, but all the artillery and stores of the insurgents fell into the hands of Calleja.[1] Don Ignacio Lopez Rayon, who had joined the insurgents at Valladolid, and was appointed confidential secretary to the commander-in-chief, returned to Guadalaxara, and succeeded in securing the military chest, containing considerable treasure, with which the insurgent chiefs withdrew to Saltillo, followed by about four thousand men. At this place it was agreed that Rayon should be left in command of the forces, whilst Hidalgo, Alende, Aldama, and Abasolo, with a small escort should proceed to the frontiers of the United States, for the purpose of collecting arms and other necessaries. But by the treachery of one Don Ignacio Elizondo, a former associate, an ambuscade was laid for them on the road, and they were all surprised and taken prisoners on the 21st of March 1811. So anxious were the royalists to extort from them information regarding the future plans of the insurgents, and the ramifications of their forces throughout the different provinces, that their trial was protracted until the end of July. They were, of course, condemned to death; and execution speedily followed. The insurgent chiefs met death with their characteristic firmness and intrepidity.

Capture and execution of Hidalgo.

National junta.

After the death of Hidalgo, a guerrilla war was carried on in various parts of the country; but as the leaders acted without concert, and no general engagement took place, it is unnecessary to follow it in its irregular course. Rayon being now left in supreme command of the troops at Saltillo, retreated first to Zacatecas, and afterwards to Zitacuaro in the state of Valladolid, which he entered about the end of May 1811. At this period in the history of the revolution, disaffection towards the Spaniards had become very general, and although the authority of the viceroy was acknowledged in all the principal cities, armed bands of insurgents overran the open country, and hardly a day passed without being signalized by a skirmish. Meanwhile, Rayon was busily employed in furthering the scheme of a national junta; being firmly convinced that a general coalition alone could enable the Mexicans to contend with any chance of success against an enemy who had the power of throwing an overwhelming force upon any particular point, and thus cutting off his troops in detail. Having bravely repulsed an attack of the royalists under brigadier Emparan, he was enabled successfully to accomplish his purpose. On the 10th of September 1811, a junta, or central government, was installed, consisting of five members, who were elected by the ayuntamiento, in conjunction with the principal inhabitants of the town and district. Amongst the principles adopted by this new junta, were, the acknowledgment of Ferdinand VII. as sovereign of Mexico, provided he would quit his European dominions, and assume the reins of government in person, and the desire of an intimate union with Spain. But, from documents published after the struggle for independence had terminated, we learn that there was but little sincerity in these professions of adherence to the mother country, and that expediency alone compelled the framers of the first declarations to have recourse to them. The king's name was yet "a tower of strength," which overawed the lower classes, and any violent expression of contempt for his authority, and renunciation of allegiance to him as sovereign, would have so shocked their notions of duty, as to create a reaction in favour of the viceroy and the royal troops.

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The intelligence of the formation of the junta of Zitacuaro, excited enthusiastic hopes throughout Mexico; and from the first moment of its establishment, the Spaniards considered it as their most formidable enemy. Its destruction, or dispersion, therefore, became an object of the last importance; and, towards the end of the year, Venegas sent peremptory instructions to Calleja to march with all his forces against the town. After overcoming hardships and difficulties, which commanded the admiration even of their enemies, the royal army arrived before Zitacuaro on the 1st of January 1812, and carried it on the following day. The junta escaped to Sultepec, where it established a new seat of government; but Calleja inflicted signal vengeance on the place, for affording shelter to the fugitives. He ordered the inhabitants to be decimated, the town to be burned, and the walls of the buildings to be levelled with the soil, the churches and convents alone being spared. By forced marches, the royal forces now proceeded to Mexico, where they were anxiously expected by the viceroy, in order to check the progress of Morelos, whose triumphant career we shall now stop to trace from the period at which he last appeared on the theatre of war.

Exploits of Morelos.

In October 1810, Morelos was appointed captain-general of the provinces on the south-western coast. In early life he had served in the corps of royal artillery, but having abandoned the army, he entered the church, and became curate of Nucupetaro. The success which at first crowned the rising of Hidalgo, inflamed him with an ardent love of liberty, and throwing aside the priestly stole, he once more assumed the profession of arms. His talents and bravery soon rendered him conspicuous, and secured for him the important command to which we have just alluded. Followed by a trifling retinue, he proceeded to the coast, and in about a month after his arrival he found himself at the head of about one thousand men. With this force he advanced upon Acapulco. Having come in sight of a numerous and well appointed body of troops, under Don Francisco Paris, the commandant of the district, he determined to attack the camp of the royalists by night, and thus commence his operations by a *coup-d'éclat*. This resolution he carried into effect on the 25th of January 1811. The enemy were surprised and put to flight in the utmost confusion, leaving in the hands of the victorious insurgents, seven hundred prisoners, (who were treated with the greatest humanity,) eight hundred muskets, five pieces of artillery, a quantity of ammunition, and a considerable sum of money. By this brilliant exploit, Morelos obtained so much celebrity, that numbers from every quarter flocked to his standard; and amongst others, Galeana, Matamoros, and three persons of the name of Bravo, one of whom, Don Nicolas, afterwards became so famous. The whole of the year 1811 was spent in a series of skilful manœuvres and petty engagements, in which the insurgents were generally successful. Multitudes of blacks now joined Morelos, but their natural ferocity required to be restrained, and strenuous efforts were made to introduce something like discipline amongst them. During January and February, several actions took place, in all of which Morelos was victorious; and amongst other advantages which he

[1] It was from the name of the bridge where this battle was fought, that Calleja took the title of Conde de Calderon.

History. 1812.

gained, was that of the capture of Tasco by Galeano and Bravo. This town, famous for its mines, is only twenty-five leagues distant from the capital, towards which the grand scene of action was gradually approaching.

Brave defence of Cuautla.

Meanwhile, intelligence reached Morelos of the arrival of the victorious royalists under Calleja; but nothing daunted by the circumstance, he determined to await the attack at Cuautla Amilpas, which is distant about two-and-twenty leagues from the city of Mexico. The town being destitute of fortifications, was open to attack; but by many ingenious expedients, it was rendered so strong, that the whole buildings and streets composed one vast system of fortifications. On the approach of the royalists under Calleja, Morelos with a small party, proceeded to reconnoitre, but advancing too near to the enemy, he was charged by a party of cavalry, and would probably have been taken prisoner, had not Galeana with a chosen band come to his rescue. On this occasion, Don José Maria Fernandez, afterwards the celebrated general Victoria, first distinguished himself, having saved the life of Galeana, by receiving a blow which was aimed at him. On the 19th of February Calleja made a general attack upon the town, his troops advancing in four columns, and with a confidence which indicated a resolution to carry all before them. They were allowed to approach unopposed within one hundred yards of the Mexican entrenchments, when so murderous a fire was opened upon them that they were forced to retire in disorder. Here Galeana engaged a Spanish colonel in single combat, and slew him in sight of both armies; an action which contributed not a little to stimulate the heroism of his own followers. Another column of royalists was as gallantly repulsed in the quarter where Morelos commanded in person, and after a conflict which lasted eight hours, Calleja withdrew from the town, leaving five hundred dead behind him. From this day he abandoned all thought of risking another general assault; but fixing his head-quarters at a little village situated about a league from the town, he wrote to Venegas for a supply of artillery and other necessaries, and having obtained it, he erected batteries, and began to cannonade and bombard the town. On the first of March he had been joined by brigadier Llano with his whole division; so that the number of his troops, and his strength in artillery, enabled him to batter both sides of the place at once. But the firmness of Morelos remained unshaken, and he determined to defend himself to the last extremity. Many instances of enterprising gallantry occurred, during this protracted siege; but a detail of these would carry us beyond our limits, and must be sought for in more detailed narratives of the revolutionary struggle. Disease and famine began to diminish the numbers of the besieged, so that the commander-in-chief formed the resolution of evacuating Cuautla; and this he succeeded in accomplishing with equal ability and success, on the night of the second of May. The troops which had been formed in columns, passed unobserved between the enemy's batteries, but on being at last discovered, Morelos gave the word for a general dispersion, as had been previously concerted, with orders to rendezvous at Izucar; and it is remarkable, that when the insurgents did muster in that place, only seventeen soldiers were amissing. Calleja entered Cuautla some hours after his opponent had left it, and there as usual, he perpetrated barbarities which will for ever leave a stain upon his reputation.

Subsequent proceedings of Morelos.

The moral effect which the siege of Cuautla produced was great, and entirely in favour of the insurgents; for the resources which Morelos had displayed, and the skill and bravery with which his military operations were conducted, extorted admiration even from his enemies, whilst they became the theme of universal praise amongst his countrymen. Leaving Izucar, he proceeded to Tehuacan, into which he made a triumphal entry on the 16th of September 1812, having defeated three divisions of the Spanish army on his way. His next exploit was the taking of Orizava, where he found nine pieces of artillery; and money, tobacco, and various stores, to the amount of above twelve millions of dollars. On the advance of a superior force, he returned to Tehuacan; and after a short respite from active duty, in the beginning of November, he set out on his celebrated expedition to Oaxaca. The royal garrison in that town was commanded by brigadier Regules, a brave officer. His defence of the place was gallant; but nothing could resist the impetuous courage of the insurgents. Oaxaca was taken, and here, after releasing all those who were under restraint for political opinions, and replacing the Spanish authorities by Mexicans, Morelos began to take measures for constituting a National Congress. But to secure from casualties, the government which it was proposed to constitute, it became necessary to make a conquest of the whole province. This was rapidly achieved; no place offering any serious resistance, except Acapulco, the siege of which lasted from February until August, when it capitulated.

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Declaration of independence.

During the absence of Morelos, every thing had been prepared by Matamoros for the meeting of the National Congress, which took place accordingly, on the 13th of September 1813, in the town of Chilpanzingo. This assembly consisted of the original members of the junta of Zitacuaro, the deputies elected by the province of Oaxaca, and others again selected by them as representatives for the provinces in the possession of the royal troops. Exactly a month after the opening of the session, an act was published, declaring the absolute independence of Mexico. It is difficult to determine what effect this bold announcement might have produced in the country, had Morelos continued his career of triumph; but his star, hitherto in the ascendant, had now reached its culminating point, and in future was destined rapidly to wane.

Morelos defeated.

Besides the achievements already recorded, the years 1812 and 1813, were distinguished by several other victories gained by the insurgent generals, Don Nicolas Bravo and Matamoros. Two actions took place at the Palmar, in the first of which Bravo defeated Labaqui, the commandant of the regiment of patriots at Vera Cruz. The engagement lasted three days, when the village in which the Spaniards had sheltered themselves was carried by storm on the 20th of August 1812. Three hundred prisoners which had been taken were offered by Bravo in exchange for his father, then in the hands of the royalists, and under sentence of death. But the proposal was disdainfully rejected, and Don Leonardo Bravo was ordered for instant execution. The conduct of the son in circumstances where severe reprisals might have been excusable, if not justifiable, reflects the highest honour on his character. He immediately set all his prisoners at liberty; "wishing," as he said, "to put it out of his own power to avenge on them the death of his parent, lest, in the first moment of grief the temptation should prove irresistible." For the present an entire division of the insurgents was placed at his disposal, and with it he penetrated into the province of Vera Cruz, where he fortified the Cerro of Coscomatepec, and defended it during September and October against the assaults of Colonel Aguilar, at the head of three thousand men. Want of provisions alone forced him to quit the place, and join Morelos at Oaxaca, which he accomplished without the loss of a single man. The second battle of the Palmar was fought on the 18th of October 1813, when the insurgents under Matamoros gained a complete victory. It was here that the regiment of Asturias, which had distinguished itself at the battle of Baylen, and bore on its standards the proud title of "the invincible conquerors of the conquerors of Austerlitz," was entirely cut off. But the time had now arrived for Morelos attempting a more decisive blow than any which had yet been struck. With seven thousand men, and a large train of artillery, he left Chilpanzingo on the 8th of November, and after sustaining incredible fatigue and privations, arrived before Valladolid on the 23d of December. This place was defended by a

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formidable force under brigadier Llano and colonel Iturbide. Confident of success, Morelos ordered his troops immediately to advance to the attack, but they were driven back with loss. Next morning, during a general review which took place within half a mile of the walls, Iturbide made a sudden attack upon the Mexicans, and threw them into confusion. They gradually rallied, however, and might have effectually repulsed the Spaniards, had not a fatal mistake occurred. A body of cavalry having come to the aid of the insurgents were by them mistaken for enemies, and fired upon, a circumstance which so enraged the horsemen that they made a furious charge upon the flank of the insurgents. Iturbide did not allow this accident to pass unimproved. He renewed his attacks, and succeeded in totally routing the whole army, which lost its best regiments, and all its artillery. This was the first discomfiture which Morelos had sustained, although he had been engaged in no less than forty-six battles, great and small. Unfortunately it was but the commencement of a series of reverses which, like fatality, attended every enterprise in which he engaged till the close of his career. He retired to Puruaran, where he was again completely defeated by Iturbide, on the 6th of January 1814. Here a number of prisoners were taken by the royalists, and amongst the rest Matamoros. Some Spaniards who had been taken in former engagements were offered by Morelos in exchange for him; but Calleja, who, on the 4th of March 1813, had superseded Venegas as viceroy, refused to accede to any such proposal. Matamoros was accordingly shot, and by way of reprisals the Mexicans put to death all the prisoners in their hands.

Further reverses and death of Morelos.

After appointing Don Miguel Mier y Teran commander of the district of Tehuacan, and Victoria captain-general of the province of Vera Cruz, Morelos himself withdrew to the southern coast, the scene of his early triumphs, and there began to recruit his forces, with his characteristic activity and resolution. But he was destined to experience defeat upon defeat. Oaxaca fell into the hands of the royalists on the 28th of March 1814, and here Don Miguel Bravo was made prisoner and executed. Galeana also, whose personal daring had so often been conspicuous, perished on the field of battle on the 27th of June; whilst the congress itself, expelled from Chilpanzingo, was forced to take refuge in the woods of Apatzingan, where it continued its labours, and on the 22d of October sanctioned the constitution known by that name. An attempt of the royalists under Iturbide to surprise this assembly having very nearly proved successful, Morelos resolved to undertake an expedition to Tehuacan, where Teran had assembled a considerable force, for the purpose of placing it in greater safety. With only five hundred followers he commenced a journey of sixty leagues through a country occupied by several divisions of the royalists. The Spaniards conceiving his force much more considerable than it really was, did not venture to attack him. But information of the real number of his followers having been conveyed by some Indians to the commandant Concha, Morelos was surprised by two parties of Spaniards, on the 5th of November 1815. He ordered Bravo immediately to continue his march with the main body, whilst he with a few men endeavoured to check the advance of the enemy. He thus succeeded in gaining time, which was his chief object; but the enterprise cost him his liberty and his life. Indeed, he seems to have anticipated such a result. "My life," he observed, "is of little consequence, provided the congress be saved. My race was run from the moment I saw an independent government established." Most of his fifty followers abandoned him when the firing became warm; but not until only one man remained by his side did the royalists venture to advance upon him, so great was the awe inspired by his personal courage. He was taken prisoner, and transferred to the capital with as little delay as possible, after experiencing the most brutal treatment at the hands of the Spanish soldiery. Both on his way to prison, and during his confinement, he maintained the same unshaken firmness and self-possession which had all along characterised him. He was first degraded, a humiliating ceremony, which affected him more than the prospect of death which was to follow; and after a trial, which was conducted by the odious Bataller, he was condemned to be shot, which sentence was carried into effect on the 22d of December 1815. He walked to the place of execution with the most perfect serenity; and after pronouncing this short prayer, "Lord, if I have done well, thou knowest it; if ill, to thy infinite mercy I commend my soul," he bound a handkerchief about his eyes, and met death with as much composure as he had ever shewn when facing it on the field of battle.

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The affairs of the insurgents fall into confusion.

After the fall of this extraordinary man the affairs of the insurgents relapsed into their former confusion. The loss of Morelos was irreparable, for he was the only patriot chief whose commands were implicitly obeyed. There was indeed no deficiency of military talent, personal courage, and enthusiasm on the part of the people, but there was a total want of unity of plan, concentration of purpose, and combination of movement. There was no want of strength, and the resources of the country which still lay within the reach of the insurgent leaders, were quite sufficient to enable them to achieve the independence of Mexico; but unfortunately these were scattered over a number of provinces amongst which no bond of union subsisted, each considering itself as isolated from the rest and entitled to act an independent part. For several years, therefore, the history of the revolution consists only of disjointed details of a wide-spread guerilla war, in which success on either side led to no important results. But before returning to Teran, Rayon, and the other principal lieutenants of Morelos, it will be necessary shortly to advert to an interesting episode in the narrative of the revolution, connected with a part of the country not yet mentioned, but which became in the sequel the scene of a momentous struggle, namely, Texas.

Texas invaded by Gutierrez.

Amongst the followers of Hidalgo, who were compelled to fly from the vengeance of the Spaniards, was Don Bernardo Gutierrez. After the confiscation of his property, which was considerable, he effected his escape to the United States, his first object being to create an interest there in the cause of Mexican independence. Although labouring under considerable disadvantages he succeeded at last in inducing a number of Americans to join the enterprise, amongst whom were several officers who had been in the field. He organized his little army, of which he was invested with the supreme command, and quitting the United States, he raised the standard of American independence and pushed forward into the interior of Texas. Great success attended the enterprise at its commencement. Nacogdoches was first taken, and the small Spanish garrison of this place joined the army of Gutierrez. He next took the town of Salcedo, and his force being daily augmented by the arrival of fresh volunteers he penetrated to La Bahia, then defended by a small stone fort. The garrison, either taken by surprise, or disaffected towards the existing government, yielded without a struggle. The principal military force of Spain in Texas was stationed at San Antonio de Bejar, under the immediate command of Don Simon Herrera, whilst Don Manuel Salcedo was at the same time governor of the province. The Spaniards lost no time in advancing to the siege of La Bahia, but with all the advantages which they possessed in superiority of force, their efforts to take the place were unavailing; and after a siege of several months they were compelled to retreat upon San Antonio, the capital, followed shortly afterwards by the republican army. The whole royal forces were mustered on the approach of the enemy, and a conflict took place at the Salado, about two leagues from the town, in which the Spaniards were defeated with great slaughter. The capital

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surrendered in a few days, Salcedo, Herrera, and all the Spanish officers resigning their swords under a solemn promise that their lives would be spared; but this pledge was most barbarously violated; thirteen prisoners of distinction, including the governor of the province, were taken to a retired place and inhumanly put to death in cold blood. Most of the royal troops joined the republican army, which gained by the conquest of San Antonio not only an accession of strength in men, but in artillery, horses, and military stores. These successes might have led to important results had they not been followed by a relaxation of discipline and a spirit of insubordination, which ultimately proved fatal to the cause. It was, however, sustained for a time by another victory gained over the royalists, and the confidence with which the troops of Gutierrez were now inspired rendered them careless about making preparations to meet the further efforts of Spain. Instead of pushing forward and raising the revolutionary standard in the internal provinces, where numbers of disaffected creoles would have joined him, Gutierrez lingered in Texas until time was afforded the viceroy and the captain-general to concentrate a force sufficient to overwhelm him. The battle was fought on the 20th of June 1813, and was afterwards followed by the expulsion of the republican leader from the command, and the elevation of Toledo, another remarkable individual, whose career we shall go back a little to trace.

Don Jose de Toledo.

Don Jose Alvarez de Toledo, a native of Cuba, entered the Spanish navy in very early life and continued in that profession until he rose to the rank of lieutenant. During the invasion of the peninsula he joined the land service and afterwards took his seat in the Cortes of Cadiz as member for the Spanish part of St. Domingo. Being detected in some correspondence in which he advocated the independence of Spanish America, he was compelled to quit the country, and sought refuge in the United States. The auspicious commencement of the enterprise under Don Bernardo attracted his attention; and resolving to co-operate with him he collected a small party with which he advanced to the theatre of war. Having fixed his head quarters at Nacogdoches, a printing press was erected, and the first paper ever published in the interior provinces of Mexico was issued in Spanish and English early in May 1813. His party was increased by daily arrivals of fresh volunteers, and he was on the eve of setting out for San Antonio when an express arrived from Don Bernardo ordering him to quit the territory immediately. He complied with this injunction; but having been elected commander-in-chief instead of Don Bernardo, who was compelled to resign his commission, he returned and was duly invested with the command in the month of July. Whilst preparations were making to meet any force which might be sent from the interior, a rumour reached head-quarters that two divisions of Spaniards were advancing upon them from different points, with the intention of concentrating their forces at the distance of three or four days' march from the capital of Texas. In this posture of affairs the choice of two courses remained for the republicans; either to fortify San Antonio and await an attack, or to advance upon the royalists before they were able to form a junction and cut them off in detail. The latter plan was that adopted. Early in August the republican army, consisting of about fifteen hundred men together with a small train of artillery, began its march. But it was soon ascertained that the two Spanish divisions had effected a junction and were advancing upon San Antonio. Under these circumstances it became necessary to alter the plan of operations, and to place the Medina, a deep ravine rather than a river, between the army and the town. Toledo disposed his army in a very skilful manner, his intention being to take the royalists by surprise; but an untoward accident rendered his design abortive. Whilst anxiously waiting for the approach of the royalists a single horseman advanced to within a short distance of the republican lines, apparently without suspicion of finding an enemy there. No sooner did he discover his situation, however, than he wheeled about and effected his escape. The republican army thus discovered, quitted its position which was most advantageous, and advanced to meet the enemy. Two small skirmishing parties having been driven back, the main army was at length discovered drawn up on very favourable ground. Toledo wished to operate only on the defensive; but a majority of the officers declared otherwise, and orders were given to advance and attack the enemy at all hazards. The battle which ensued was contested with great obstinacy, but the republicans were ultimately put to flight, and no quarter was given on the field. It was found impossible to rally the fugitives; and although an attempt was made in the spring of 1814 to renew the enterprise, it totally failed.

History. 1815-17.

Condition of Mexico at this period.

We have already alluded to the distracted situation of Mexico after Morelos ceased to direct the operations of the independents. The country was divided into districts, in each of which one of his former lieutenants assumed the command; and a brief sketch of the career of the principal chiefs is all that we can afford in this place. Don Nicholas Bravo succeeded in escorting the deputies in safety to Tehuacan, where they were received at first with great respect by General Teran. But disputes soon arose between the civil and military authorities, each becoming jealous of the power of the other, and suspecting designs which were never even contemplated. The person whom the Congress had appointed to manage the public purse, contrived to embroil himself with Teran, by demanding possession of the money and stores which that general had with infinite pains collected. Teran finding himself thus reduced to a state of dependence on the Congress which had just thrown itself upon his protection, resolved to discard its authority altogether, and accordingly dissolved it in December 1815. This step has been generally blamed as at least precipitate. There can be no doubt that it was attended by disastrous circumstances; for from that moment confusion became worse confounded; Victoria, Guerrero, Bravo, Rayon and Teran, confining themselves each to his own separate circle, where they were crushed in turn by the superiority of the common enemy. Teran attempted to established a government himself, but none would acknowledge it. He continued, however, to prosecute that sort of desultory warfare so characteristic of the time, in which he was commonly successful. But the want of arms cramped his efforts, and to supply the deficiency, he undertook an expedition to the coast, escorted by only three hundred men. His enterprise proved unsuccessful, although conducted in a masterly manner, and he distinguished himself by making a military road, which is allowed to be a very extraordinary work, and by a victory gained over a royalist force consisting of eleven hundred men. Compelled to return to Tehuacan, he fortified himself in Cerro Colorado, where, being besieged by a royalist force of four thousand men, he was forced to surrender on the 21st of January 1817, but on terms more favourable than had ever yet been granted to a revolutionary chief.

During the prosperity of Morelos, Rayon acted as one of his lieutenants, commanding chiefly in the mountainous parts of Valladolid. His principal strong-hold was in the Cerro de Coporo, where, in the early part of 1815, he successfully repulsed a very formidable attack of the royalists; but this fortress was ultimately carried during his absence, and Rayon himself was soon afterwards taken prisoner, and confined in the capital until the year 1821. The fate of Don Nicholas Bravo was exactly similar to that of Rayon. Guerrero occupied the western coast, and here he maintained himself in the fastnesses of the Sierra Madre, until the year 1821, when he joined Iturbide.

History. 1817. Sufferings of Victoria.

But amongst all the insurgent chiefs none harrassed the Spaniards so much, or was so closely pursued by them, as Victoria. Occupying the important province of Vera Cruz, during the years 1814 and 1815, he succeeded in cutting off almost all communication between the capital and the only port through which intercourse with Europe was carried on. The necessity of keeping this channel open, induced the viceroy from time to time, to throw fresh bodies of troops into the province in which it is situated. Victoria was thus gradually driven from his strongholds, yet he maintained the unequal contest for upwards of two years, until the villages refusing him supplies, the last remnant of his followers forsook him, and he was absolutely left alone. Still his courage was unsubdued, and his resolution not to submit to Spanish authority on any terms, remained unshaken. He scorned the offers that were made him, and accompanied by a single attendant, sought an asylum in the depth of the forests. For a time the Indians supplied him with provisions; but the viceroy dreading that he might again emerge from his hiding-place, ordered out a thousand men, in small detachments, literally to hunt him down like a beast of prey. His hair-breadth escapes, and the romantic life which he led, render this part of his history so extraordinary, that its truth might be doubted did not the unanimous testimony of his countrymen confirm the story of his sufferings. Pursued from place to place, he was for several years subjected to every species of pain and privation. For thirty months he never tasted bread, but subsisted chiefly on the fruits of the soil, and occasionally on the flesh of animals, until he accustomed himself to an abstinence of four or five days at a time. During all this time he never saw the face of man, and remained unsheltered, save by the woods, whose thorny brakes tore his clothes to rags, and lacerated his body. In short, when the events of 1821 induced him to quit his fastnesses, the very Indians whom he first met, fled in terror from such a phantom. Such inflexible virtue, and unflinching patriotism, merited public gratitude, and his countrymen shewed it to Victoria. He became the first president of the Mexican republic.

State of the country

Some facts relative to the state of the country require to be mentioned, before we advert to the enterprize of Mina, the only event of importance which occurred prior to the breaking out of the second revolution. The cause of independence had been gradually gaining ground amongst the people, particularly since 1812, when the constitution which was sanctioned by the Cortez of Cadiz, was extended to the transatlantic dominions of the crown. It took effect in Mexico in the autumn of the same year; and for two months during which the liberty of the press was tolerated, so many pamphlets against Spain and Spanish domination, were published, that the tranquillity of the capital was endangered by the excitement thus produced. These political writings created a national feeling, which became everywhere predominant. By the new constitution, several important privileges had been conceded to the natives; amongst the rest, the right of electing the members of the Cabildo, and the deputies to the Cortez. It was in exercising these that the true state of public opinion became apparent. Out of six hundred and fifty-two elective appointments, not one was bestowed upon a European; and most were conferred upon individuals identified with the cause of independence. In law, also, matters underwent so complete a reform, that a creole might now hope for a favourable decision, provided his cause was a good one. Thus by the new constitution, the reverses sustained by the creole leaders in the field, were more than counterbalanced; and it appears from several important documents which were found in the archives of the vice-royalty, after the independence of Mexico had been effected, that for many years the confidential servants of the crown felt the impossibility of maintaining its authority there, unless supported by an overwhelming military force, such as the mother country could not supply, and that any prospect of permanently suppressing the revolution had become hopeless. Under the mild sway of admiral Apodaca, who succeeded Calleja in the vice-regal authority, all was done that could be done to secure the allegiance of the natives. The arrival of fresh troops from the Peninsula, enabled him to extend his military ramifications throughout the whole country, and enforce obedience even at the most distant points. Thus, as we have seen, the revolutionary chiefs were successively crushed; and the facilities afforded to all who had embarked in the enterprise for reconciling themselves with the government by accepting pardon, reduced the number of those actually in arms in 1816, and the three following years, to a very inconsiderable amount.

History. 1817.

Inroad of Mina.

After her last patriotic chiefs had quitted the open field, and sought refuge in the mazes of the forests, a deep gloom hung over the affairs of Mexico, which remained for a long time unbroken, save by the sudden inroad of Mina.[1] This remarkable individual landed in Mexico on the 15th of April 1817, at a time most unpropitious for the undertaking in which he had embarked. All the independent leaders had disappeared from the scene, except those with whom it was a disgrace to be associated. Such was the infamous Padre Torres, who exercised a despotic sway over the Baxio, which he parcelled out amongst his military commandants, men whose only recommendation was implicit obedience to the will of their chief; and who obtained honour and rewards in the inverse ratio of their humanity and virtue. From a fortress, on the top of the mountain of Los Remedios, Torres proved the scourge of the whole country around, sparing none who had the misfortune to offend him, and laying waste the most fertile portion of Mexico. Robinson mentions several instances of the most wanton barbarity on the part of this man, which do violence to human feeling; yet it was under his auspices that the only shadow of a government, termed the junta of Jauxilla, was still kept up by the insurgents. Nevertheless the feeling throughout the country was so decidedly in favour of independence, that the success of Mina would scarcely have been doubtful, had he not laboured under very great disadvantages. He was not a Mexican, but a Spaniard; and he was against a disunion of the two countries, wishing only for the re-establishment of the constitutional system of 1812. We cannot follow him throughout his short but extraordinary career, but his principal exploits may be narrated. With about two hundred men, he left Soto la Marina, the place of his landing, and pushing forward to the confines of the table land, defeated a body of four hundred royalist cavalry. About the middle of June 1817, he reached the Hacienda de Peotillos, and on a little eminence which commanded the plain, awaited a royal army two thousand strong, with a force of only one hundred and seventy-two men, a small detachment being left in charge of the baggage. Incredible as it may appear, he totally routed the royal troops; and two days afterwards took the town of Pinos by surprise. He continued to penetrate into the interior, until he fell in with the advanced guard of the insurgents of the Baxio, with whom he reached Sombrero on the 24th of June, having in thirty days traversed a tract of country two hundred and twenty leagues in extent, and been three times engaged with an enemy greatly superior in numbers. In conjunction with his new

[1] Don Xavier Mina, a famous Spanish guerilla chief, and nephew to Espoz y Mina, still more celebrated for his patriotic efforts in Spain. Don Xavier was driven from his native country after an unsuccessful attempt to create a rising in favour of the Cortez at Pampeluna, subsequently to the dissolution of that assembly by the king; but not discouraged by his first failure, he repaired to the New World, a wider theatre of action.

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allies, and some recruits, by whom his force was swelled to about four hundred, he advanced upon San Juan de los Llanos, and on the 29th of June totally defeated the royalists under general Castañon. Of seven hundred men whom the latter led into the field, only one hundred and fifty effected their escape, all the rest being either killed, wounded, or taken prisoners; and amongst the slain was Castañon himself.

Defeat and death of Mina.

Soon afterwards Los Remedios, the strong-hold of Padre Torres, was invested by a royalist force of five thousand men, under the command of general Linan. Previous to the commencement of the siege, Mina had quitted this place at the head of nine hundred insurgent cavalry, intending to harass the besiegers by keeping up a desultory guerilla war; but his movements were watched by another body of Spaniards, eight hundred strong, so that the necessity of striking a blow elsewhere, became apparent. He accordingly advanced by secret marches upon Guanajuato, and on the 24th of October, at nightfall, succeeded in carrying the gates, and penetrating into the very centre of the town. At this critical moment the courage and subordination of his troops failed them; they refused to advance a step farther; and time being thus allowed the garrison to arm themselves, they attacked the insurgents, who, by the general's orders, dispersed with the utmost precipitation. Mina himself was taken prisoner three days afterwards, and sent to the head-quarters of Linan, there to remain until intelligence of the manner in which he was to be disposed of, should arrive from Apodaca. The viceroy dispatched orders for his immediate execution, and the sentence was carried into effect on the 11th of November. Mina perished in his twenty-eighth year, and appears to have met his fate with great firmness. He is uniformly represented by those who knew him, as a young man of uncommon talent; uniting, in a remarkable degree, energy and personal courage with coolness and judgment. He was besides untainted with that ferocity which characterised many of the guerilla chiefs of the Peninsula. Not long after his death, Los Remedios was evacuated by the insurgents, and with the exception of Padre Torres and twelve of Mina's division, none of the fugitives escaped. The ferocious commander himself, was a few months afterwards run through the body by one of his own officers. The fort of Jauxilla, the only other stronghold of the Mexicans in the interior, surrendered on the 6th of March 1818. One or two insurgent chiefs attempted to make a stand against the Spaniards, but without success; they gradually disappeared, so that in July 1819, not one remained of those who had taken any lead in the revolution.

State of the independent cause.

The cause of Mexican independence seemed now to have sunk to such a low ebb, that the viceroy wrote in great confidence to the court of Madrid, representing the country as so tranquil and submissive to the royal authority, that he would answer for its safety, without the assistance of a single soldier from Europe. But the appearances on which he relied proved altogether fallacious. The suspension of hostilities afforded the creole troops who had assisted Spain against their country an opportunity of reflecting upon their situation, and the object for which they had shed their blood so profusely. The disbanded insurgents were allowed to mingle freely in their ranks, and proselytes to the principles of the revolution were rapidly made even in the royal camp itself. In private, the bulk of the people were as warmly attached to them as ever, although they did not openly boast of holding such doctrines. About the middle of 1820 accounts arrived in Mexico of the revolution in Spain, occasioned by the revolt of the army in the Isla de Leon; and it soon became public that orders had been sent to Apodaca to proclaim the constitution, which Ferdinand VII. had been compelled to adopt. The era of 1812 was revived, and the public mind thrown into a ferment, which the viceroy, from his restricted powers, found it impossible to allay. Besides, the Mexicans were divided amongst themselves, one party professing a sincere adherence to the constitution, whilst another class was as strongly attached to the old system. Necessity, of course, compelled the viceroy to take the oath to the constitution; but he favoured those who were opposed to it, and took secret measures for effecting its subversion.

History. 1821.

Defection of Iturbide.

General Armigo, who was partial to the constitution, was dismissed from the command of the army stationed between the capital and Acapulco, and his place supplied by Don Augustin Iturbide, to whom allusion has already been made. This officer, a Mexican by birth, early distinguished himself, and was upon the eve of joining the insurgents, in 1808, when either, as he himself says, disgusted with their projects, or, as they on the other hand assert, having been rejected on account of the exorbitant rate at which he estimated his services, all communication between them was broken off, and he joined the royal standard. Having distinguished himself in the action of Las Cruces, he from that moment rose rapidly. His activity and knowledge of the country recommended him as a fitting agent to execute any dangerous enterprise; and in these he was almost uniformly successful. As a guerilla chief he had displayed uncommon military talent; and when intrusted with a more important command, he inflicted two of the most severe blows which the insurgent cause sustained, in the battles of Valladolid and Puruaran. The lustre of his military exploits was, however, tarnished by a cruelty towards prisoners seldom evinced even amongst the Spaniards. His cold-blooded executions, together with the rapacity and extortion which he exercised in the government of the Baxio, where he commanded, became at last so odious, that the viceroy found it necessary in 1816, to recal him to the capital, where he remained unemployed till 1820. It was at the close of this year that Apodaca had recourse to him as a fit agent for executing his plans against the constitution. He was offered the command of a body of troops stationed upon the western coast, at the head of which he was to proclaim the re-establishment of the absolute authority of the king. The proposal was accepted, and Iturbide left the capital in February 1821, but with intentions very different from those by which the viceroy supposed him to be actuated.

Second Mexican revolution.

Four years of leisure and reflection had enabled this man to form a proper estimate of the strength of parties in Mexico, and to perceive that the authority of Spain might be shaken off provided the creole troops could be brought to co-operate with the old insurgents. But no suspicion of his real motives was entertained by the viceroy, and the escort of half a million of dollars destined for embarkation at Acapulco was implicitly confided to him. Iturbide, however, having arrived at a town called Iguala, situated about one hundred and twenty miles from the capital, took possession of the money; and on the 24th of February he commenced the second Mexican revolution, by proposing a new government, which is well known under the title of "the plan of Iguala." His force at this time amounted to eight hundred men, who unanimously took the oath of fidelity to the "plan," whilst a copy was transmitted to the viceroy, and to all the governors of provinces. This celebrated document consisted of twenty-four articles, the principal points embodied in which were, a declaration of Mexican independence; the recognition of the Catholic religion as the national creed; the establishment of a constitutional monarchy; the formation of a junta of government; an offer of the crown to Ferdinand VII., and in the event of his refusal to the Infantes Don Carlos and Don Francisco de Paula, provided any of them would consent to occupy the throne in person; an abolition of castes, and of the despotism of military commandants; the formation of an army for the support of religion, independence, and union, and for guaranteeing these three principles, whence it was to be called the army of the three guarantees;

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1821.

Success of Iturbide.

a general amnesty to all who should give in their adhesion to the "plan;" and other provisions of less importance.

When the viceroy learned the defection of Iturbide, and the system of government which he had concocted, he concentrated a force upon the capital for the purpose of defending it, and frustrating the plans of the revolutionists. But hesitating to put himself at the head of the troops, the Europeans became alarmed at his indecision and delay, and without further ceremony deposed him, as they had done Iturrigaray, placing at the head of affairs, Novella, an officer of artillery. By this unwise proceeding a schism was created in the capital, which afforded Iturbide an opportunity of prosecuting his scheme without interruption. He effected a junction with general Guerrero, and from this moment his success became certain. On his route to the Baxio, great numbers of men and officers joined his standard, and whilst both the clergy and the people declared in his favour, the most distant districts gave in their adhesion to his "plan" of government. Before the month of July the whole country had recognised his authority, with the exception of the capital, where the viceroy had shut himself up with the European troops. On his march to invest the city of Mexico, intelligence reached Iturbide that the new constitutional viceroy and political chief, O'Donoju, had arrived at Vera Cruz. He immediately requested an interview with this functionary, and allowed him to advance as far as Cordova, where a meeting took place. The adoption, by treaty, of the plan of Iguala was proposed to O'Donoju, and by him agreed to. In the name of his master the viceroy recognised the independence of Mexico, and gave up the capital to the army of the three guarantees. Such was the treaty of Cordova, which was signed by Iturbide, "as the depository of the will of the Mexican people," and by O'Donoju, as the representative of Spain, on the 24th of August 1821. By virtue of this treaty, Iturbide obtained possession of the capital, which he entered in triumph on the 27th of September. Novella and such of the Europeans as chose to leave the country, were allowed to quit the Mexican territory, and private property was strictly respected. The junta proposed in the plan of Iguala was installed without loss of time. It was composed of thirty-six persons, who elected a regency, consisting of five individuals, with Iturbide at their head. He was at the same time created generalissimo and lord high admiral, and had assigned to him a yearly salary of one hundred and twenty thousand dollars.

Usurpation of Iturbide.

The career of Iturbide had hitherto been triumphant, and to all appearance the country had gone along with him. As far as concerned the separation from Spain, this was really the case; but when the details of the future government came to be discussed, matters very soon took a different turn. By one rash, if not despotic step, the power of Iturbide was overthrown. In assembling the National Congress, he suggested the necessity of the deputies pledging themselves to his plan, by swearing to observe it before they took their seats in the congress. This displeased many of the old insurgents, particularly those who had acted a conspicuous part in the cause of independence, such as Victoria, Bravo, and Guerrero. The first Mexican Cortes met on the 24th of February 1822, and its members soon split into three distinct parties; first, the Bourbonists, or those who adhered to the plan of Iguala, and wished to establish a constitutional monarchy, with a prince of the house of Bourbon at its head; secondly, the Iturbidists, who adopted the plan of Iguala, with the exception of the article in favour of the Bourbons, wishing to elevate Iturbide himself to the throne; and, thirdly, the republicans, who denied the right of the army to pledge the nation to the plan of Iguala, and desired a central or federal republic. Amongst the Bourbonists were many honourable and enlightened men; but they soon ceased to exist as a separate party, the Cortes of Madrid having declared the treaty of Cordova "to be illegal, null and void, in as far as the Spanish government and its subjects were concerned." They formed a junction with the revolutionists whenever it was necessary to check the growing power of Iturbide, whose ambitious projects now became more and more conspicuous. A protracted contest ensued; the Congress meeting the demands of the regency for money with a charge of wasteful expenditure, whilst the president loudly denounced the Congress, accusing them of wilfully exposing the army to the greatest privations, and the country to the most imminent danger. Of the multifarious contentions which followed, it is unnecessary to give any detailed account. Iturbide strenuously urged the necessity of augmenting the army; but the Congress, instead of adding to the regular troops, brought forward a measure for reducing the army from sixty to twenty thousand men, the deficiency to be supplied by calling out an auxiliary force of thirty thousand militia; and notwithstanding all the exertions of Iturbide, this proposal was carried by a large majority. The friends of the president now saw that his influence was on the wane, and that if they wished to raise him to the throne, the attempt must be made before the memory of his former services was obliterated. Their measures were concerted accordingly. Upon this occasion none of the commissioned officers was employed. The sergeants of three regiments then in garrison in the capital, which were known to be much attached to Iturbide's person, were the instruments selected for carrying into execution their designs. On the night of the 18th of May, having assembled the soldiers, they marched out of their quarters, and followed by a motley group of leperos or lazzaroni, drew up in front of Iturbide's house. At ten o'clock commenced the shouts of "Long live Iturbide, Augustin the First, Emperor of Mexico;" and the *vivas* and firing continued during the whole night. Next day the Congress assembled to discuss his title to the crown; and although many were opposed to the measure, the galleries and places leading to the hall were so crowded with the armed partisans of Iturbide, that the Congress was under the necessity of consenting to the wishes of the soldiery, and of a blind infuriated mob, the worst perhaps in the world. Iturbide had recourse to the old and stale manœuvre of pretending to consent with reluctance to the will of the people; he was accordingly proclaimed emperor, with the sanction of the National Assembly; and the choice was ratified by the provinces without opposition.

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1822.

Conduct of the new emperor.

Had the new emperor confined his authority within constitutional bounds, and endeavoured to conciliate the congress, he probably might have remained in quiet possession of the throne of Mexico. The limits of the imperial prerogative, and the authority of the legislative body had yet to be defined, and before this could be accomplished they required to be discussed. The privileges demanded by the emperor were quite inconsistent with any thing like regulated freedom. He wished to have the right of appointing and removing at pleasure the judges of the supreme court; he claimed a veto upon all laws, not excepting the articles of the constitution, then under discussion; and he recommended the establishment of a military tribunal in the capital, with powers very little inferior to those exercised by the Spanish commandants during the revolution. Some of his former demands the Congress had agreed to concede, but this last attack upon their liberties they indignantly repulsed. Such decisive conduct led at once to an open rupture. Upon the night of the 26th of August, fourteen deputies of liberal principles were by the emperor's orders arrested, and thrown into prison. This bold step was followed by a series of reclamations and remonstrances on the part of the Congress, which only tended to widen the breach, and to render an accommodation impossible. Iturbide determined to end the dispute, as Cromwell had done under similar circumstances. He sent an officer to the hall of the Congress with a simple notification that the assembly had ceased to exist, and an order to dissolve it by force should any resistance be offered

History. 1822-23.

to his authority. But no compulsion was required. The deputies dissolved their sessions at once, and the doors of the chamber were closed by the officer whom the emperor had commissioned to make known his will. This took place on the 30th of October 1822. On the same day, a proclamation announced the dissolution of Congress, and appointed a new legislative assembly called the Instituent Junta, consisting of forty-five members selected by Iturbide himself. The state of the treasury being laid before this body, a forced loan of two millions and a half of dollars was decreed; and as the exigencies of the state were urgent they applied for its immediate use a large sum belonging to Spaniards who had quitted or were about to quit the country, and which had been accidentally detained at Perote.

Fall of Iturbide.

This assembly, however, never possessed any influence in the country, and the tranquillity which Iturbide enjoyed proved of short duration. An insurrection broke out in the northern provinces in the month of October, which might have proved serious under an efficient leader, though it was soon crushed by the imperial troops. But matters were brought to a crisis by the defection of General Santa Anna, governor of Vera Cruz. Towards the close of the year 1822, he published an address to the nation, in which he reproached the emperor with having broken his coronation oath by dissolving the Congress; and declared his resolution, and that of the garrison under his command, to reassemble this body, and to support whatever form of government it might please to adopt. Iturbide, instead of endeavouring to conciliate the insurgents, as Santa Anna's troops were called, determined to repress the revolt by force of arms. With this view he despatched General Echavari, a Spaniard, in whom he placed the highest confidence, with a force sufficiently strong to invest Vera Cruz. But in the meantime Victoria quitted his hiding place in the mountains and joined Santa Anna, who immediately yielded to him the chief command. He could not have adopted a wiser measure. Victoria's principles and character being well known, the natives rallied in great numbers round his standard. Echavari finding that public opinion was everywhere decidedly against the emperor, made common cause with the garrison of Vera Cruz, and induced his whole army to follow his example. On the first of February 1823, an act was signed called the act of Casa-Mata, by which the armies pledged themselves to effect the re-establishment of the national representative assembly, and to support it against all attacks. As soon as this was known the provinces rapidly gave in their adhesion to Victoria; and Bravo, Guerrero, and Negrete having joined the republican army, defection now became so general, that Iturbide abandoned all thoughts of resistance. On the 8th of March he assembled all the members of the old Congress who were in the city, and tendered his abdication; but the number present being insufficient to constitute a house, it was not accepted. On the 19th of March he repeated the offer, and stated at the same time his intention of quitting the country, lest his presence might give rise to further dissensions. The Congress refused to accept of the abdication, as that would have implied that he had legal right to the crown; but they willingly allowed him to quit the kingdom with his family, and assigned him a yearly pension of about five thousand pounds. Iturbide was allowed to choose his own escort to the coast, and selected General Bravo for the purpose, by whom he was accompanied to Antigua, near Vera Cruz, where a ship was freighted by government to convey him to Leghorn.

History. 1824-25. His re-appearance and death.

The old Congress was immediately convoked; a provisional government was established; and an executive, composed of three persons was appointed. These were Generals Victoria, Bravo, and Negrete, the two former being natives, and the latter a European of distinguished talents. They conducted the affairs of the country until a new Congress was assembled in August 1823; and in October 1824, the federal constitution was definitively settled by the latter. But before alluding to this subject, we shall here briefly notice an event which again placed the tranquillity of the country in jeopardy. Iturbide the ex-emperor had proceeded to Leghorn by a ship freighted to convey him thither. He subsequently visited London, whence, on the 11th of May 1824, he embarked with his family for Mexico. In taking this step he seems to have acted under the impression that a little time would prove as fatal to the popularity of his rivals as it had been to his own; and that the eyes of his countrymen would then be directed to himself, as the only means of preserving them from anarchy. A decree of Congress, dated the 28th of April preceding, had declared him a traitor, and placed him out of the protection of the law, in the event of his again appearing in Mexico. Disregarding this denunciation, he landed about the middle of July, at Soto la Marina, where he introduced himself in disguise and under a feigned name. But he was apprehended by General Garza, and shot a few days afterwards; a measure, the severity of which has been justified by the impossibility of otherwise avoiding a civil war.

Form of government

The form of government adopted by the representatives of Mexico, was that of a Federal Republic, upon the plan of that of the United States, the deviations being few and unimportant. Nineteen states and four territories, each of which manages its own internal concerns, compose the confederation; whilst the whole are cemented into one body politic, by certain general laws and obligations, contained in the federal constitution of the 4th of October 1824, of which an outline will be afterwards given. For some months Generals Victoria, Guerrero, and Bravo, exercised the supreme executive power; but it soon became necessary to elect a president, and the choice fell upon Victoria, whilst Bravo obtained the vice-presidency. The devoted patriotism of Victoria, and the eminent services rendered by him to his country in its struggle for independence, gave assurances of tranquillity and freedom; and the first Congress of Mexico under its new constitution, assembled on the 1st of January 1825. It is worthy of remark, that about the same time the independence of Mexico and that of some of the south American republics was recognised by the British cabinet.

Subsequent disorders and revolutions.

But the hopes which had been formed regarding the peace and prosperity of Mexico, have proved altogether fallacious. Since the above period repeated revolutions have disturbed and agitated the country. From the moment at which the war of independence commenced, the nation became divided into two parties; natives, and guachupines, or European Spaniards. The former consisted of those who wished to establish the independence of Mexico; the latter were warmly attached to the dominion of Spain. To these two parties, succeeded the Imperialists and Republicans; and, lastly, came the Centralists and Federalists, which, under the sobriquets of Escosses and Yorkinos, appellations derived from two masonic societies, have for several years divided the republic.[1]

Intrigues of Rivero, and others.

Since the success of what has been called the plan of Iguala, every new project or scheme of reform, either in the organic laws, or in their administration, has been styled "a

[1] The term Escosses is synonymous with aristocrat, and that of Yorkino with democrat. The first society, which is supposed to be of Scotch origin, is composed of many of the largest proprietors in the country, particularly those who possessed titles of nobility before the revolution; besides a number of officers of distinction, and wealthy individuals belonging to different professions. The members of this association are mostly men of moderate principles, and opposed to violent changes, although sincerely attached to the cause of independence. They were the advocates of conciliating measures, and would have been contented with a prince of the royal blood of Spain, as constitutional king of Mexico; and on this account their adversaries the Yorkinos, charge them with "Bourbonism." Until 1825, the Yorkinos did not exist as a party; but in the summer of that year, a number of individuals not connected with the Escosses, though not violently

History. 1827-28.

plan." The first of these which seriously disturbed the administration of Victoria, was set on foot in 1827 by Montano, at Ottumba. The document which he published, proposed the total suppression of all secret societies, an entire change in the administrative functions of the government, and the expulsion of the resident minister of the United States, who, as we have seen, was an active agent in the formation of the Yorkino lodge; and the blow aimed at him must doubtless be attributed to that circumstance. Early in January 1828, Colonel Rivero attempted to excite an insurrection against the government in support of Montano, but he was put down by a proclamation declaring Montano guilty of treasonable designs. The vice-president became involved in the intrigues of the time, and went so far as to accuse the president of acting under Yorkino influence, and sanctioning schemes highly injurious to the country. Bravo suddenly left the capital, and, stationing himself at Zalancingo, published a manifesto, in which, notwithstanding his relation to the Escosses, he declared himself in favour of the plan of Montano. This conduct on the part of Bravo, completely changed the position in which he and his friends had formerly stood. The advocates of order and moderation appeared in the character of enemies to the established system, whilst the executive was compelled by their aggression to throw itself into the arms of the Yorkinos, whose chief, General Guerrero, assumed the command of the government troops. Bravo was proclaimed a traitor, and although at the head of a considerable military force, he surrendered without any serious opposition to Guerrero, whom Victoria had despatched to suppress the revolt. The Congress found Bravo guilty of treasonable designs against government; and by a decree dated the 15th of April 1828, he was banished from the country for a period of seven years.

Pedraza elected president.

The time was now approaching, when it became necessary to find a successor to Victoria as president of the republic; and from the blow which the Escosses had received in the banishment of their chief, their advocates confidently anticipated a triumph in the elevation of Guerrero. But the period fixed by the constitution was still distant, and before its arrival, another candidate was brought forward to oppose the Yorkinos. This was General Gomez Pedraza, at that time minister of war and marine, and a very efficient member of the Mexican cabinet. The whole of the Escosses party, together with a portion of the more moderate Yorkinos, united in his favour; and the canvass was conducted with the greatest zeal, nay even rancour. After an arduous contest, Pedraza was elected president by a majority of two votes; and the Escosses looked forward to a long period of tranquillity under his firm and vigorous administration. But unhappily these sanguine anticipations were not realized. The disappointed party was loud in its denunciation of the successful candidate. His friends were accused of bribery and corruption, and even charged with procuring the interference of the military in some of the states. By a singular anomaly in the constitution of Mexico, a period of nearly seven months is allowed to elapse, before the president who has been elected, can take possession of the government; so that time was thus afforded the defeated party to collect its strength, and prepare for a vigorous effort to annul the election by an appeal to arms.

Attempt of Santa Anna to annul the election

It was at this time that General Santa Anna, whom we have already had occasion to mention, began to play a distinguished part in public affairs. He exercised great influence over his troops, with whom, as well as with the people, he was very popular. He had previously been driven from the office of vice-governor of Vera Cruz and had taken refuge in Jalapa. As soon as he learned the result of the general election he gained over the troops in that place, and seizing upon the military chest and stores, he marched early in September to Perote, which he took possession of at the head of about eight hundred men. There he published a manifesto in the shape of an address from the liberating army to the people of Anahuac. In this document he denounced the legislature as the secret abettors of the plan of Montano, and as intriguing against the liberties of the people in favour of a Bourbon prince. He charged Pedraza with having shewn himself inimical to the interests of the people, and with having succeeded in his election by fraudulent means, contrary to the wishes of the majority, and he declared it to be the will of the people that Guerrero should assume the reins of government. It was further proposed that the people and army should annul the election of Pedraza; that the Spanish residents should be banished, on the assumption that they were the primary cause of the grievances from which the Mexicans suffered; that Guerrero should be declared president; and that the legislature should proceed to a new election. This audacious "plan" was vigorously protested against by Victoria; and addresses reprobating the conduct of Santa Anna poured in from all quarters. Perote was invested by a government force, and the refractory general was compelled to make a precipitate retreat in the direction of Oaxaca. In the capital some of the Yorkinos, and amongst others one of the chief leaders, Zavala governor of the state of Mexico, evinced a disposition to make common cause with Santa Anna; and Zavala, upon his being denounced to the Congress as a correspondent of that general, confirmed the accusation by flight. The mass of the population, however, remained undisturbed, and Guerrero himself resolved quietly to await the course of events.

History. 1828.

Expulsion of the Spaniards

From a feeling of hostility towards the natives of the peninsula, which prevailed pretty generally throughout Mexico, matters were very speedily brought to a crisis. On the night of the 30th November 1828, a battalion of militia, headed by the ex-Marquis of Cadeña, and assisted by a regiment under colonel Garcia, took possession of the artillery barracks at the Acordada, surprised the guard, seized the guns and ammunition, and intimated to the president their determination either to compel the Congress to issue a decree for the banishment of the Spanish residents in the course of twenty-four hours, or to carry this resolution into effect in a more summary manner by massacring all who should fall into their hands. The military force at the immediate disposal of the president was too small to make any effectual resistance, and the night was wasted in fruitless attempts at negociation. Next morning the insurgents were joined by general Lobato, a partizan in the revolutionary war, Zavala, the ex-governor of Mexico, the Yorkino deputy Cerecero, a party of militia, and a number of officers, together with a vast multitude of leperos, who were promised the pillage of the capital as the reward of their services. Guerrero was immediately proclaimed; and the general, after haranguing the populace, quitted the metropolis with a small retinue, and took up a position about three leagues from the gates, where he actively employed himself in collecting a force to support the measure of his partizans. Unfortunately for the executive, the president became suspected of favouring the Yorkinos; and the Congress not only refused to entrust general Victoria with extraordinary powers, but thought it necessary repeatedly to call upon him to assert his authority by making a vigorous use of those with which he was

opposed to them, were united as a rival sect under the above designation, because they derived their origin from the masonic lodge of New York, which transmitted through Mr. Poinsett, the American Minister, the diplomas and insignia requisite for the establishment of an affiliated lodge in the capital of Mexico. They are the ultra-federalists, or democrats of Mexico, and profess the most violent hostility to Spain and Spanish residents, whom the Escosses protected after their power to injure the country had ceased. At the head of the Escosses lodge was General Bravo; whilst the grand master of the Yorkinos was General Guerrero; and an opportunity was soon afforded for putting to the test the strength of the adverse parties.

History. 1829.

constitutionally invested. But Victoria does not appear to have acted with his usual decision and prompitude, probably from an aversion to shed Mexican blood. By the second of December the insurrection had made alarming progress, the doors of the prisons having been forced open and the criminals allowed to escape. The government now hazarded an appeal to arms, and succeeded in recovering several important posts from the insurgents; but they were regained on the following day after a severe contest, in which several officers of distinction fell on both sides, besides a great number of men. The ranks of the insurgents were soon filled up, whilst those of the government remained without reinforcement. Indeed they gradually lost ground, and on the night of the 3d many officers, foreseeing how the struggle would terminate, sought safety in flight. During a suspension of hostilities which took place on the 4th, General Guerrero entered the city with a considerable force, and the appearance of these fresh troops was a signal for the recommencement of firing at every point. But the termination of this calamitous struggle was rapidly approaching. The government troops were gradually driven back towards the palace, and the leperos, spreading themselves like a torrent over the town, committed every species of excess. They directed their vengeance chiefly against the Spaniards; but all who were supposed to possess wealth fell victims to the rapacity of an unbridled mob. These disgraceful scenes continued for two days, and property to a very great amount, was destroyed or changed owners. The pillage was at last put a stop to by Guerrero, whom the president had appointed minister of the war department, Pedraza having quitted the capital just in time to save his head. Several provinces eagerly espoused his cause, but he sacrificed his individual rights and personal feelings in order to preserve the peace of his country, and recommended submission to an unconstitutional president in preference to a civil war. The troops scattered throughout the country gradually went over to the victorious party, and state after state, in rapid succession, declared in favour of the expulsion of the Spaniards and the presidency of Guerrero. Pedraza formally resigned his office, and was allowed to quit the territories of the republic. A new congress having assembled on the first of January 1829, Guerrero was declared duly elected, and General Anastasio Bustamante, a distinguished Yorkino leader, was associated with him as vice-president, whilst other offices of government were filled by members selected from the Yorkino body. It is not a little remarkable that Santa Anna, the prime mover of this "plan," was not permitted to take an active part in its execution. He remained closely besieged in a convent in the vicinity of Oajaca, and was forced to surrender at discretion to General Calderon on the 14th of December. But before that time the fate of Mexico had been decided, and any partial success which might have attended the government forces would have been of little avail. Santa Anna laid down his arms only to be invested with the supreme military command of the republic twenty-four hours afterwards.

Invasion of Barradas, and abdication of Guerrero.

The success with which this daring revolt was crowned cannot be otherwise regarded than as a most unfortunate circumstance. The interference of the military to reverse the decree of the people in the case of a general election is always a fatal precedent, and one entirely subversive of civil rights. The first event which disturbed the country after the elevation of Guerrero was its invasion by Barradas in the summer of 1829. This general having collected a considerable number of troops in the island of Cuba, for the purpose of making a last effort for the recovery of Mexico, transported his force to Tampico, and immediately commenced warlike operations. In the meanwhile the president was invested with extraordinary powers, a step which the legislature considered as fully justified by the occasion. Santa Anna was dispatched to repulse the invading force, in which he completely succeeded, at the same time taking Barradas himself prisoner. But Guerrero was now destined to taste the cup which he had mixed for his predecessor and rival. His alleged reluctance to lay down the powers of dictator, which had been conferred on him in the above emergency, led to various revolts and insurrections in various parts of the republic. The state of Yucatan declared against the federal government and in favour of the central system. Early in December 1829, Bustamante, the vice-president, flew to arms, and having placed himself at the head of the army of Mexico, which was stationed in the state of Vera Cruz, he advanced upon the capital, everywhere denouncing the abuses and usurpations of Guerrero. Santa Anna issued a proclamation in support of the government; but long before he could reach the capital the revolution had been completed. Guerrero first resigned his dictatorial powers, and then convoked the Congress and appealed to it for support; but it was all in vain; he was ultimately compelled to abdicate. The army then elected Bustamante as his successor, whilst Santa Anna, following the example of Guerrero, retired to his estates, and tranquillity was soon restored.

History. 1832.

Fall of Bustamente; election of Santa Anna.

At this period it required no great gift of prophecy to predict, that even the shadow of the constitution of 1824 would not long survive. Mexico was now beyond all doubt subjected to a military despotism; and a pretext or cause for prostrating Bustamante in his turn, could not long be wanting. It was enough that the daring, crafty, and cruel Santa Anna, the conqueror of Barradas, was living in retirement and disgrace, hatching new schemes of revolt. From that period, Mexico has presented a kaleidoscopic exhibition of factions and parties. It would require volumes to detail the series of manœuvres, of *gritos* and insurrections, which seated Santa Anna ultimately in power, and made him the representative of that amalgam of all parties which has been designated by a cant term in which the most incongruous ideas are jumbled together. In July 1832, the Ayuntamiento and people of San Felipe de Austin, unanimously gave in their adherence to the plan of Vera Cruz, and to the principles of the republican party, headed by General Santa Anna. This example was followed by other states, and Santa Anna assumed the reins of government. In April following he drove out the Congress; and in 1835, Gomez Farias, who had been elected vice-president, was driven into exile. Santa Anna was now undisputed master of the destinies of Mexico, for all the effective power of the republic had been confided to him. During the summer his attention was engaged in the alteration of the government, from a federal to a central form; from a coalition of several states, to the concentration of the powers of all in one point. He was again successful in this new "plan," and centralism with a *de facto* dictatorship succeeded to the federal republic. The states were converted into departments, and the legislatures cut down to a council of five. This new order of things was acknowledged by the whole country, with the exception of Texas, which was warmly attached to federalism. But in order to understand the true position of affairs in that state, and also the causes of the events which have recently taken place there, it will be necessary to trace back the history of its settlement.

Texas; history of its settlement.

The colonies of Texas owe their existence to a colonel Austin, who in the year 1821 was authorised by the Mexican government to introduce and settle three hundred families upon favourable conditions. The first settlement was made on the river Brazos, in December 1821. The original grant was confirmed by the new government in 1824; and since that period, several new contracts for the establishing of colonies have been entered into. All the other grants in Texas, excepting a few in favour of Mexican citizens, were modelled upon those of Austin. The Mexican government drew up a number of colonization laws, by which, in as far as they had reference to Coahuila and Texas, it was stipulated that Catholicism should be maintained as the esta-

History. 1832.

blished religion of the country; that all foreigners, provided they were married and followed a profession, should be considered as naturalised in three years; and that Coahuila and Texas together should constitute one of the united federal states of Mexico, whilst the colonists should be considered as Mexicans, and governed like the other inhabitants of the republic. The nominal grantee of the land is called the empresario; and according to the terms of the contract, he is considered merely as a trustee of the government, having no title himself to the land within the limits of his colony, excepting upon the condition of settling a certain number of families in a given time. The settlers themselves receive a title for each family to a square league, upon the express condition of settlement and cultivation, and the payment of certain trifling charges within a limited period. These conditions constituted the basis of all the land titles in Texas, but were coupled with the provision, that all right and title would be forfeited, if the grantee should abandon the country, or sell his land before having cultivated it. These privileges were conceded to a great number of empresarios; and many of them, forgetting the contingent character of their own rights to the soil, and the conditions upon which their future colonists were to receive allotments of land, proceeded at once to make out scrip, or lots of land, which was sold in the United States, to a considerable amount. A regular company, called the Galveston Bay and Texas Land Company, was formed in New York, for the purpose of facilitating the disposal of tracts of country, to which no one had as yet acquired the smallest title. Many respectable individuals, eager to obtain such extensive grants of land for the trifle at which they were advertised for sale, made extensive purchases; but when they emigrated to Texas for the purpose of taking possession of their vast estates, they found to their mortification and surprise, that they had no more claim to them than any other person who might have come to Mexico from a foreign country. So flattering, however, did the prospects to emigrants appear, that great numbers flocked to Texas from the United States; indeed the country may be said to have been peopled from that quarter.

Dispute with the Mexican government.

Various causes have contributed to create a misunderstanding between the inhabitants of Texas as an individual state, and the executive of the Mexican republic. The administration of Bustamante, was regarded by them as a military despotism; and the arbitrary acts which were committed by the military subalterns of the republic, became at last so oppressive, that they had recourse to arms, and took Fort Velasco on the 27th of June 1832. On the 16th of July following, Colonel Mexia, second officer of the second division of the liberating army as it was then called, of Montezuma, anchored off the mouth of the Brazos, with his fleet of five sail, and a force of four hundred men. He had been informed by the military commandants of Fort Velasco, Anahuac, and Nacogdoches, that the movements which had taken place there had for their object the separation of Texas from Mexico; and the object of his expedition was to crush the insurrection before it proceeded any farther. On his arrival, the civic authorities of Brazoria, presented to him a statement of their case, in which they inveighed against the arbitrary and unconstitutional measures of Bustamante; and declared their unabated attachment to their adopted country, and particularly to its "distinguished chieftain Santa Anna." This was quite satisfactory to colonel Mexia, who being in the interest of Santa Anna, was desirous to gain adherents to the plan of Vera Cruz, and to the principles of the republican party, of which Santa Anna was the head. The troops of the government still held out in some parts of Texas; but they were finally reduced, and about the beginning of September, the warlike commotions had ceased in these colonies. Could the inhabitants of Texas have foreseen what the revolt of Santa Anna was to lead to, they would have displayed less eagerness in professing their attachment to him.

History. 1832-33. Proposed separation of Coahuila and Texas.

At a meeting of the people of Texas in 1833, there was drawn up a constitution, in which, amongst other important matters, they pointed out the necessity of a separation from Coahuila, and affirmed their resolution to form themselves into a full and independent state of the Mexican confederacy, by the name of the state of Texas. The chief reasons assigned by this general convention for the contemplated disunion, were, the dissimilarity between Coahuila and Texas, in soil, climate, and productions, in common interests, and partly in population, so that laws happily constructed for the benefit of Coahuila, and conducive to its best interests, might be ruinous to Texas. The seat of government was also stated to be too remote, being fixed at Saltillo, and the inhabitants of that part of the state were almost exclusively of Spanish descent. From this circumstance alone, it is obvious that the union of Coahuila and Texas as a single state of the Mexican federal republic, must from the first have been odious to the colonists of American origin; and it was likely to become more so, in proportion as fresh supplies of emigrants poured in from the United States. With the increase of their numbers, the Americans began to think and to feel, that they were strong enough to manage their own state affairs in their own way. Hitherto they had been treated with great liberality and indulgence, and had been entrusted with the administration of their own laws, which were any thing but the ancient laws of Mexico. Colonel Austin, who had for many years been member of Congress for Texas, was in the spring of 1833 chosen once more to represent the country. He was also charged with the duty of submitting to the general government in Mexico, the new constitution which had been formed; but finding it difficult or impossible to effect his object, he wrote a letter to some of his friends in Texas, in which he did not conceal his sentiments as to the necessity of Texas taking matters into her own hands, and doing herself justice. This letter was intercepted by government, in consequence of which Austin was imprisoned upon a charge of entertaining treasonable designs. He was ultimately released; but there can be no doubt that the circumstance awakened the jealousy of the Mexican government.

Causes of the rupture with Mexico.

Before proceeding to narrate the leading incidents of the struggle with Mexico, it is necessary to premise, that the unappropriated lands, although state property, cannot be granted to any one without the sanction of the general government. We have already noticed the great rage for land speculation which existed not only in Mexico, but in the United States. It became at last insatiable, and an extensive system of fraud was the consequence. In 1834, a company of these speculators induced the legislature of Coahuila and Texas, to grant them four hundred square leagues of public land, in consideration of a payment of twenty-thousand dollars. This transaction was, of course, disavowed, and the grant annulled by the Mexican government; but it led to the dispersion of the legislature, and the imprisonment of the governor Viesca. Yet, so far from putting a stop to the system of fraudulent dealing, it seems only to have encreased it; for according to the best information which has been obtained, the four hundred leagues became in the hands of the speculators, nearly as many thousands. This interest in the soil of Texas, so widely diffused amongst a speculative people extending from Boston to New Orleans, could scarcely fail to create a sympathy, which, in the event of another rupture between the colonists and the government of Santa Anna, might compromise the neutrality of the United States. Such a rupture actually soon took place, and the colonists flew to arms. But as partial statements cannot be trusted, it would be premature to give any thing like a history of recent events; and we shall therefore confine our-

History. 1834-35.

selves to a few leading facts, respecting which there seems to be no difference of opinion.

Amongst a number of petitions which accompanied the plan of the new constitution prepared by the convention, there was one regarding the tariff, to which the attention of the general congress was particularly called. The prayer of the petitioners was, that there should be granted them for three years, the privilege of introducing, free of duty, such articles as were indispensable to the prosperity of Texas. An exemption from payment of duties for two years was obtained, at the expiration of which period, an attempt to establish customs was forcibly resisted by the colonists. This, together with a demand for the persons of those who had been concerned in the grant of the four hundred leagues of land, were the immediate precursors of hostilities. But before these events occurred, the conduct of Santa Anna had begun to be suspected in Coahuila and Texas; and the consequence was, that the state government, which had been removed to Manclova, a more central position, denounced his conduct as unconstitutional. This produced a counter declaration from Saltillo, in which a number of persons avowed themselves favourable to Santa Anna's measures, and threw themselves under his protection. They elected an officer of the permanent army governor of the state, took possession of the hall of Congress, and disannulled all the decrees passed by the constitutional state congress, from the first of January 1823, to July 1834. The contentions of the two factions which had thus sprung up, tended more and more to spread anarchy and confusion throughout the state, and to distract the minds of the people. The American colonists, whose partiality to a federal republic is well known, were loud in their censure of Santa Anna, who was now close at hand, quelling an insurrectionary movement in Zacatecas. Many refugees from that state arrived in Texas, and contributed to increase the alarm by stating, that the orders of Santa Anna were to cut down all Americans. Viesca collected another state government, in which were many members of the last legislature; and he issued proclamations and addresses, calling the inhabitants of the state to arms, against the encroachments of that military power, which, he said, threatened their very existence, not only as a state, but as a people. The press groaned under conflicting statements. Santa Anna was stigmatised as a dictator, and death was denounced against all his supporters who should enter Texas. Taxes were refused; the custom-house officers were expelled; the custom-houses were shut up; and the laws of Mexico were set at defiance. In these circumstances, Santa Anna, who had succeeded in gaining all the other states of the republic, found it necessary to turn his attention to Texas, which had not only refused to acknowledge a central government, but was in absolute rebellion against it.

Hostilities; declaration of independence.

In September 1835, General Cos, the confidential friend and brother-in-law of the central chief, landed at Compano at the head of four hundred men, destined to reinforce the garrison of San Antonio de Bejar. He issued a proclamation, stating that the objects of his mission were, the enforcement of the laws, the collection of the revenue, the punishment of fraudulent speculators, and the disarming of the insurgents. He thus disclaimed any intention of disturbing the great body of the colonists; but his proceedings roused them to arms, and the war commenced in earnest. The Mexican troops succeeded in reaching San Antonio, although it seems to have been the intention of the Texians to prevent the intended junction of the forces. General Cos immediately prepared for the defence of the capital, by establishing barricades and other works; but the Texians, notwithstanding their inferiority of numbers, succeeded in reducing the place in October, when the Mexican general and his troops were permitted to retire from the province. After the fall of the capital and the expulsion of Cos, the victorious party quarrelled amongst themselves, and violent party dissensions broke out. Some advocated the formation of a coalition with the northern Mexican states, whilst others determined on attempting an independent government. A declaration of independence was published in December, by about ninety Americans, who, acting not in a representative capacity, but for themselves individually, called upon their fellow-citizens to follow a similar course. Early in March 1836, a convention of delegates from the various settlements of Texas, having assembled at a place called Washington, issued a more formal declaration of independence, setting forth the grievances which impelled the people to take that step. This declaration was signed by forty-four delegates, of whom only three or four were Mexicans by birth. The convention, in their detail of grievances, enumerate as such, the overthrow of the federal constitution by Santa Anna, to uphold which, they considered the Mexican government as pledged; the refusal to secure on a firm basis trial by jury, and to separate Coahuila from Texas; the forcible dispersion of the legislature; the imprisonment of Colonel Austin; and the tyranny and oppression of the military commandant. They complained that the government had demanded the surrender of a number of citizens, and had ordered military detachments to secure and convey them into the interior for trial; that it had not only made piratical attacks upon their commerce, but had demanded a surrender of their arms; that their country was attacked both by land and by sea; and that attempts had been made to excite the Indians to massacre the defenceless inhabitants of the frontiers. With respect to the justice of these complaints, it would be rash to offer any opinion, until the restoration of peace and order shall have afforded the historian an opportunity of collecting all the facts of the case, and from ascertained data, drawing dispassionate conclusions. If the people of Mexico preferred another form of government to that established in the year 1824, they had the right to effect this change, because it is generally admitted, that in a republic the majority must govern. The Texians have no just ground for asserting their independence upon that account; but they have an unquestionable right, if they choose to abide by the consequences, to try the strength of parties upon so momentous a question, as whether Mexico shall be a central or a federal republic. They acknowledge themselves citizens of Mexico; and as there seems to be nothing in the colonization laws which promises to colonists in particular the perpetuity of the constitution of 1824, their argument for independence on that head falls to the ground. They complain, also, of being subjected to the despotism of the priesthood; but by the colonization laws it was declared, that the Catholic religion alone should be tolerated, and thus another of their arguments is disposed of. Lastly, with regard to trial by jury, it is a thing quite unknown in Mexican jurisprudence; and in respect to the separation of Texas from Coahuila, and the other grievances complained of, it is impossible at present to offer any satisfactory opinion. But whether reasonable or not, these complaints, and the redress demanded, were soon to be enforced by an appeal to arms.

History. 1835-36.

Advance of Santa Anna against Texas.

In their first declaration of independence the people of Texas undoubtedly supposed that the internal divisions of the country would afford sufficient employment for the arms of Santa Anna; forgetting that there existed in Mexico an inveterate prejudice against the American colonists, which might induce them to overlook for a time all minor differences, and unite as against a common enemy. Hence the defeat of Cos actually extended the authority and influence of Santa Anna, and he was thus enabled to bring nearly the whole resources of Mexico to bear upon Texas. It soon became apparent, also, that from the strict alliance which existed between Santa Anna and the Catholic clergy, religious intolerance was mixed up with political animosity against the American colonists; and that thus they had every reason

History. 1836.

to expect a furious and desperate conflict. Yet they made little preparation for the approaching contest, and their early operations were both feeble and ill-advised. It was soon ascertained that Santa Anna was on his march, at the head of a powerful army, advancing towards the Rio del Norte; and early in February 1836, he established his head-quarters on the Nueces, to the eastward of that river. Here he issued a proclamation, in which he denounced the insurgents as a mob of ungrateful adventurers, on whom the authorities of Mexico had incautiously lavished favours which they had failed to bestow on Mexicans, and who had raised the standard of rebellion, in order that that extensive and fertile department which they inhabited might be detached from the republic. By his plan of operations he proposed to advance in two columns, one directed against San Antonio, and the other against La Bahia, which place was lower down the coast; intending by this means to intercept all communication between the Americans and the Gulf. His effective force has been variously estimated from five to ten thousand men, including a fine corps of cavalry. Upon the 23d of February, the Mexicans, four thousand strong, attacked the fort of Alamo, in San Antonio, but were gallantly repulsed. The invading army was more successful in its assault on Bejar, which, after sustaining a siege of two weeks, was taken by Santa Anna. The garrison, consisting of one hundred and eighty-seven men, were all slain in the siege, or put to death afterwards; and the loss of the Mexicans in storming the place was estimated at one thousand killed or mortally wounded. The second division of the Mexicans advanced towards La Bahia, or Goliad. This town was occupied by Colonel Fanning, who, conscious of the inadequacy of his force to defend the place, evacuated it, but not till it had been committed to the flames. In his retreat, however, he was intercepted by the Mexican army, which was about three times as numerous as his own, and after a severe conflict forced to surrender. The commander, along with about five hundred Texians, were cruelly put to death by the Mexicans, who still remembered their old system of treating prisoners of war.

Total defeat of the Mexican army.

This military execution caused much excitement, and instead of deterring the Texians from prosecuting their purposes, it exasperated them in the highest degree. For some time a panic seemed to prevail, and the colonists fled, leaving all kinds of property behind them. The retreat of the Texians suddenly ceased, and General Houston having rapidly counter-marched a distance of about sixty miles, came up with Santa Anna. On the 21st of April, near the banks of the San Jacinto, a fierce and sanguinary conflict took place between the Mexicans and Texians, in which the former were defeated with great slaughter, and above seven hundred taken prisoners, amongst whom was the commander-in-chief himself. A great quantity of arms, and about twelve thousand dollars, likewise fell into the hands of the victors. This unexpected event totally changed the aspect of affairs; and the success of the Texians, which had at one time appeared impossible, became at least probable. Their rising fortunes stimulated their zeal and activity. Many of the more pacific of the colonists had sought refuge in the neighbouring states; but their place was speedily supplied by numerous adventurers from the United States. On the 15th of May, a convention was held at Velasco, in Texas, where it was stipulated that hostilities should cease; that the Mexican army should quit Texas; and that Santa Anna should be sent to Vera Cruz, upon condition of his agreeing neither to take up arms against the Texians, nor to exercise any influence to cause them to be taken up during the struggle for independence. This agreement was disapproved of by the president *ad interim* of Mexico, and General Filasola, who was next in command to Santa Anna, was ordered to give up the command of the army to General Urrea, and repair to Mexico to answer for his conduct. By the latest accounts it appears that a large body of Mexican troops had marched upon Texas; and that by orders of Congress, General Gaines, commander of the United States' army, had crossed the Sabina, and established his head-quarters at Nacogdoches, in Texas, whence, however, they were afterwards withdrawn. The right of the United States to interfere in any shape may well be questioned; but whether they will actually interpose, or what course they will pursue, it is impossible at present to determine. In the meantime, volunteers from that country are crowding to Texas, and by them will the independence of the revolted Mexican province be effected, if this should ever take place.

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After what has already been stated, it would be superfluous to discuss the question whether the Texians have any legitimate right to separate themselves from Mexico, and to establish an independent government. In regard to the abstract merits of the case, the Mexicans, as we have already stated, appear to have all the arguments upon their side. Since the majority of the Texians are emigrants from the United States, an opinion very generally prevails that their object in separating Texas from Mexico is to engraft it upon the American Union. There are good grounds for believing that this conjecture is correct; and if it be so, their proceedings must be held as altogether unjustifiable; nor would the conduct of the American Congress be less so, if it should accept them, in the event of the successful issue of their scheme. But such a gross violation of the rights of an independent power is not likely to occur, nor has Congress as yet in the least degree countenanced the revolt.

III.—STATISTICS OF MEXICO.

Boundaries and extent.

The republic of Mexico is bounded on the east and south-east by the Gulf of Mexico and the Caribbean sea; on the west by the Pacific ocean; on the south by Guatemala; and on the north by the United States of America. The river San Pedro, which rises near the lake of Peten, and after traversing a considerable tract of country is joined by the stream of Yalchilan, constitutes the greater part of the national boundary of Guatemala and Mexico; the remainder is a chain of mountains, which separate it from the territory of the Mayas, an Indian tribe inhabiting a portion of Peten. The boundary line between Mexico and Louisiana commences with the river Sabina, at the point where it falls into the Gulf of Mexico about 29. north lat., 94. west long., and follows its course as far as its junction with the Red river of Natchitoches. The course of the latter then marks the frontier up to the 100th degree of west longitude, where the line runs directly north to the river Arkansas, which it follows to its source in the 42d degree of north latitude. From this point another direct line is drawn, immediately upon the forty-second parallel, to the coast of the Pacific; thus dividing between the two rival republics the whole continent of North America, with the exception of the British possessions. The frontier, as above defined, was fixed by the treaty of Washington, which was concluded in the year 1819. The exact line of demarcation is at present of little importance, except with regard to the north-eastern frontier, where the valuable province of Texas might prove a source of contention, were the limits of the two countries not definitely fixed. The rest of the boundary line is as imaginary as a parallel of latitude. Between Mexico and the western territories belonging to the American United States, and on either side of the Missouri, a vast tract of country intervenes, inhabited only by Indian tribes, who have never yet been subjugated, and acknowledge no authority.

From the southern extremity of Yucutan, the province which joins Guatemala, to the northern extremity of California, Mexico extends over twenty-seven degrees of latitude, or 1876½ English statute miles. In breadth it varies considerably, being only one hundred and twenty-five miles across at its lower extremity. It continues to expand,

Statistics. however, until it joins the United States; and its greatest breadth, which is in the parallel of 30° north latitude, from the Red River of Texas, to the coast of Sonora, Humboldt has estimated at about eleven hundred miles. According to the same great authority, the superficial extent of the Mexican territory is 118,478 square leagues of twenty-five to the degree. There is, besides, a tract of country situated between the northern extremity of New Mexico and Sonora, and the boundary line agreed to by the treaty of Washington, the exact extent of which is not yet ascertained. Of this vast territory about 82,000 square leagues are situated without the tropics, or under the temperate zone; whilst the remaining leagues of surface lie within the tropics, or what is usually entitled the torrid zone.

The most important part of Mexico is that which has been denominated the Table-land. The Cordillera of the Andes, after traversing the whole of South America and the Isthmus of Panama, expands or separates, upon entering the northern continent, into two branches which, diverging to the east and west, but still preserving their northerly direction, leave in the centre an immense platform, or elevated tract of country. The height of the whole is considerable, varying from six thousand to eight thousand feet above the level of the Pacific, and thus equalling that of Mont St. Bernard and other remarkable summits of the Old World. The eastern branch declines as it approaches the north, and about the 26th parallel of north latitude it subsides to nearly a level with the ocean; but on the west the chain continues in an almost uninterrupted line to the frontiers of the United States, where it splits into various ramifications, known chiefly by the name of the Rocky Mountains. The summits of some of the detached mountains penetrate beyond the line of perpetual snow, and attain an elevation almost equal to that of the highest of the Andes. Such are the volcanic peaks of Orizaba, Popocatepetl, and Toluca. But these are merely insulated heights, or inferior chains, which bear no relation of parallelism to the general direction of the Cordillera, and can scarcely be said to interrupt that vast level, as smooth almost as the ocean, which stretches from one extremity of Mexico to the other. Thus the table-land is not as in Quito and other parts of the southern continent, an interval between opposite ridges, but generally speaking, it is the most elevated portion of the ridge itself. In Peru, and other parts of South America, immense transverse valleys continually interrupt the progress of the traveller, and prevent him from proceeding in any other manner than on horseback or on foot; but in New Spain, carriages roll without obstruction, from the city of Mexico to Santa Fé, a distance of above fifteen hundred miles.

Volcanos. Volcanos.—That great chain of volcanic mountains which extends with little interruption from lat. 24° north, to lat. 2° south, appears to commence in Mexico. The most northern volcanic craters occur near the town of Durango in the former degree of latitude; but there are no active volcanos till we reach the parallel of the city of Mexico, between which and the little towns of Cordova and Xalapa, there is a group which rival in elevation the loftiest peaks of the continent. The heights of the principal peaks were measured by M. Humboldt. Popocatepetl, or the Smoking Mountain, called by the Spaniards the great volcano, is 17,968 feet in height; the Iztacci-Huatl, or the White Woman, the Sierra Nevada of the Spaniards, is 16,000 feet; the Citlal-Tepetl, or Starry Mountain, otherwise called the Peak of Orizaba, is 17,697 feet; and the Nauhcampa-Teptl, or Coffre de Perote, is 13,633 feet in height. The first of these volcanos is continually burning, but for centuries it has ceased to eject from its crater any thing except smoke and ashes. Luminous exhalations, also, constantly irradiate the summit of Orizaba, which is covered with perpetual snow. In 1545, an eruption of this volcano took place, and the crater continued to burn during twenty years. In the same province is that of Tuxtla, in which a considerable eruption took place in 1793, the ashes of which were carried as far as Perote, a distance of fifty-seven leagues. On the western side of the city of Mexico, are the volcanos of Jurulla and Colima, the latter of which throws up smoke and ashes, but has not been known to discharge lava. Jorulla, which is situated between Colima and the city of Mexico, is of much more recent origin than any of the others. In 1759, according to Humboldt, the plains of Jorulla upon the shores of the Pacific ocean, formed the scene of one of the most tremendous catastrophes that ever shook the globe. In the month of June in that year, subterraneous noises of the most frightful description were heard, accompanied with frequent earthquakes, which succeeded one another during fifty or sixty days. In the early part of September, all became tranquil again; but towards the end of that month the same horrible noises recommenced, and a tract of ground from three to four miles square, swelled up like an inflated bladder; flames issued through a thousand apertures, and fragments of burning rocks were propelled upwards to a vast height; whilst through the dense envelope of smoke and ashes, illuminated by volcanic fire, the softened surface of the earth was seen to rise and fall like an agitated sea. The rivers Cuitimba and San Pedro precipitated themselves into the flaming chasms. Thousands of small cones varying from six to ten feet in height, issued from the volcanic ground; and some of these yet retain a temperature equal to that of boiling water. Vapour also ascends to the height of from twenty to thirty feet, and, in not a few of them, subterraneous sounds still startle the traveller. In the midst of these cones six large masses, elevated from three to sixteen hundred feet each above the former level of the plain, arose out of a chasm which ranges from north-north-east to south-south-west. The loftiest of these elevated masses, is the great volcano of Jorulla, which burns continually, and has thrown up upon one side an immense quantity of scorified and basaltic lavas, containing fragments of primitive rocks. These eruptions continued till February 1760, since which period, they have become less frequent. The active volcanos above noticed, appear to be connected by a chain of intermediate ones, running in a parallel direction, and exhibiting the clearest indications of a similar origin. Farther south, in the republic of Guatemala, the volcanos increase greatly in number; but in this quarter, instead of being placed nearly at right angles to the chain of the Cordilleras, they run parallel to it.

Minerals. Minerals.—In the Old World granite, gneiss, mica slate, and clay slate, often form the central ridges of the mountain chains; but in the Cordilleras of America, these rocks seldom appear at the surface, being covered by masses of porphyry, greenstone, amygdaloid, basalt, obsidian, and other rocks of the same class. The granite which here generally forms the lowest stratum, appears at the surface in the little chain that borders the Pacific ocean, and which, on the side of Acapulco, is separated from the mass of high country by the valley of Peregrino. The beautiful port of Acapulco is a natural excavation in granitic rocks. As we ascend towards the table-land of Mexico, we see it rise through the porphyry for the last time, between Zumpango and Sopilote. Farther to the east, the mountains of Mixteca and of Zapateca, in the province of Oaxaca, are formed of the same rock, together with gneiss, traversed by veins of quartz containing gold. The great central plateau of Anahuac, as the tract of country comprehended between the fourteenth and twenty-first degrees of latitude is called, appears like an enormous dyke of porphyrytic rocks, distinguished from those of Europe by the constant presence of hornblende, and by the absence of quartz. These rocks contain immense deposits of gold and silver. Basalt, amygdaloid, trap, gypsum, and primitive limestone, form the predominating rocks. The strata succeed each other here in

Statistics. the same order as in Europe, excepting that syenite alternates with serpentine. The secondary rocks equally resemble those of the Old World; but hitherto no considerable beds of rock-salt or of coal have been discovered in the plateau of Mexico; whilst, on the other hand, these substances, especially the former, appear to exist in great abundance, to the north of the gulf of California. In some parts the porphyry presents itself in gigantic masses, which assume extraordinary shapes, resembling ruined walls, bastions, towers, and the like. The porphyritic traps in columns, which terminate the mountains of Jacal and Oyamel, are crowned with pine trees and oak, which materially add to their picturesque appearance. It is from these mountains that the ancient Mexicans obtained the obsidian, of which they formed their sharp edged instruments. The Coffre de Perote is a porphyritic mountain, resembling an ancient sarcophagus, surmounted by a pyramid at one end. The basalts of La Regla, of which the prismatic columns, an hundred feet in height, have their central parts harder than the rest, form the native decorations of a very beautiful cascade.

Rivers and Lakes. RIVERS AND LAKES.—The rivers of Mexico are unimportant, and the want of water in an agricultural, and of navigable streams in a commercial point of view, are found to be serious disadvantages. The Rio del Norte, indeed, may have a course of about fourteen hundred miles; and that of the Rio Colorado on the west, may be about half that length; but flowing as they do through a part of the country as yet of little commercial importance, although possessed of almost unlimited capabilities, viz., Texas, they do not at present facilitate the trade of the country to any great extent. The Rio Grande de Santiago or Tololotlan, formed by the union of the rivers Lerma and Las Laxas, is likely to become the most valuable. It rises in the very centre of Mexico, and after traversing the Baxio, empties itself into the Pacific near San Blas. In all the equinoctial parts of Mexico, only small rivers are met with; but their estuaries are very broad. The narrow form of the continent prevents the union of a great body of water; whilst the rapid declivity of the Cordillera gives rise to torrents rather than rivers flowing with moderate velocity and capable of being navigated. Amongst the small number of rivers which are found in the southern part of the country, the only streams which are likely to become useful mediums of intercourse with the interior, are the Rio Guasacualco and the Alvarado, both of which are to the south-east of Vera Cruz, and seem well calculated to facilitate communication with the republic of Guatemala. There is also the Rio de Montezuma, which carries the waters of the lakes and valley of Tenochtitlan to the Rio de Panuco. The lakes of Mexico are very numerous, and appear to be the remains of others of vast extent, which formerly covered a much larger portion of the lofty plateau. The principal are the great lake of Chapala, in Guadalaxara, which covers nearly one hundred and sixty square leagues of country; the lakes of the valley of Mexico, which extend over one-fourth of its surface; the lake of Pazcuaro, in the province of Valladolid, one of the most picturesque spots on the globe; and the lakes of Mextitlan and Parras.

The whole of the eastern or Atlantic coast of New Spain, may be viewed as an immense wall, against which the trade-winds, and the perpetual movement of the waters from east to west, heave up the sand which the agitated ocean holds in suspension. An immense current rushes in from the southern Atlantic ocean, and after sweeping through the Gulf of Mexico, issues by the Bahama channel or Gulf of Florida. The sand accumulated by the revolving waters from the peninsula of Yucatan to the mouth of the Rio del Norte, insensibly contracts the basin of the Gulf of Mexico, by adding to the breadth of the continent. The rivers which descend into the Caribbean sea materially contribute to fill up and elevate the bottom. The whole of the eastern coast, from the eighteenth to the twenty-sixth degree of latitude, is thus obstructed by bars, so that none but vessels drawing little water can venture to cross them without danger of striking. The violent storms which prevail during several months, both on the eastern and western coasts of the isthmus, are also serious obstacles to navigation. From the autumnal equinox to the spring, north-west winds prevail in the Gulf of Mexico: they are at their greatest height in the month of March, but during September and October they are generally mild. On the eastern coast the navigation is very dangerous in the months of July and August, when the dreadful tornadoes from the south-west prevail. At this time, and even at a much more advanced period of the season, the anchorage in San Blas, Acapulco, and all the ports of the central republic, are exceedingly unsafe. During the fine part of the year, from October till May, the calmness of the ocean is again disturbed in these road-steads by the furious winds from the north-east and north-west, known by the names of Papagayo and Tehuantepec. Statistics.

Climate. CLIMATE.—The climate of Mexico comes next to be considered; and here it may be stated generally, that in a country so extensive as Mexico, and distinguished by such remarkable physical peculiarities, any theory that may be proposed on this subject must be liable to great exceptions. An exposed situation, or one sheltered from the winds of the north-west, which occasionally sweep the country with incredible violence; proximity to the Pacific, where the air is milder; the want or abundance of water, and the like;—all these are circumstances which affect the temperature in the most opposite manner, even at the same height and in the same parallel, and render it impossible, by the standard of elevation alone, to form any exact idea of the climate of the table-land. Humboldt gives 76° of Fahrenheit as the mean heat of the coast, and 64° of Fahrenheit as the mean heat of the table-land. The same accomplished traveller mentions a striking instance of the local peculiarities by which the temperature is modified, namely, that sugar is successfully cultivated four thousand feet above the degree of elevation assigned by him from previous experiments as productive of the *minimum* of heat necessary for raising the cane. Indeed, every little break or descent in the surface of the table-land, leads us naturally to an increase of temperature, as the ascent from the coast does to a diminution of it. The transition is sometimes extremely sudden, a deep ravine being sufficient to change the stunted growth peculiar to the central plateau to the luxuriancy of tropical vegetation. It is impossible to proceed either to the eastward or to the westward of the capital, without repeatedly experiencing these transitions in the course of a single day. The natives, without inquiring into their origin, express the fact by styling these hot low ravines, *Tierra Caliente*, a term uniformly signifying those parts of Mexico in which the heat is sufficient for producing the fruits of the tropics; and, with the exceptions mentioned, they are all situated upon the sea coast on either side of Mexico, the table-land lying between them. *Tierra Fria* is the term applied to the mountainous districts which rise above the level of the capital, as high as the limits of perpetual snow; whilst *Tierra Templada*, or temperate region, in its most extensive acceptation, embraces all that is not included under either of the other two divisions. This zone is chiefly situated on the declivity of the Cordillera, at the height of from four to five thousand feet above the level of the sea; and here the genial temperature of spring almost constantly prevails. Intense heat and excessive cold are equally unknown. Unfortunately, however, this medium elevation is nearly the same as that at which the clouds float above the plains adjacent to the sea; and hence these temperate regions, although situated upon elevated ground, are sometimes enveloped in dense fogs. It is to be observed, however, that the terms by which the several zones are dis-

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tinguished are used in a very arbitrary manner; and thus what is called a temperate country by the inhabitant of one part of Mexico would be considered as a cold country by the denizen of a warmer region.

All the regions denominated cold enjoy a mean temperature of from 52° to 56° of Fahrenheit, equal to that of France and Lombardy. Still the plants of Europe do not reach the maturity which they attain in their native soil, and vegetation is generally much less vigorous. May not this arise from the rarity of the air, a plentiful supply of the elements of which it consists being essential to vegetables acquiring the highest degree of size and strength of which they are susceptible? On this supposition we can easily account for vegetation being less luxuriant upon the ridge of the Mexican Cordillera than upon the plains to the north of the tropic, even in cases where the mean temperature is lower. In the equinoctial region of Mexico, and even as far as the 28th degree of north latitude, there are only two seasons; that of the rains, which commences in the month of June or July, and ends in September or October; and the dry season, which continues from October till the end of May. The formation of clouds and their precipitation in various forms, generally commences on the eastern slope of the Cordillera. These phenomena, accompanied with thunder storms, extend in succession from east to west, in the direction of the trade winds, so that the rain falls fifteen or twenty days later on the central plateau than at Vera Cruz. From the parallel of 24° to that of 30°, the rain falls less frequently, and continues a shorter time; but the deficiency is compensated by the snow which, from the 26th degree of latitude northwards, is deposited in considerable quantities.

The climate of the provinces denominated *internas*, and which are situated within the temperate zone, is distinguished by a striking inequality in the temperature of the different seasons; the winters being very cold, whilst the summers are comparatively very warm. To this, as well as to other local causes, must be attributed the aridity which characterises a considerable portion of the plateau of Anahuac. There are few springs in the mountains; and the water, instead of collecting in little subterraneous basins, filters through the earth or porous rocks, and loses itself in crevices formed by volcanic eruptions. The evils arising from aridity have increased since the Europeans first took possession of Mexico. The conquerors not only destroyed trees without supplying their place by young plants, but by artificially drying up extensive tracts of country, they occasioned a still more important evil. The muriates of soda and of lime, the nitrate of potass, and other saline substances, cover the surface of the soil. Still a great part of Mexico may be classed with the most fertile countries of the earth, for there every species of vegetable production is found, or may be successfully cultivated. On the ascent from Vera Cruz, climates, to use an expression of Humboldt's, succeed each other in layers; and the traveller passes in review, in the course of two days, the whole scale of vegetation, from the parasitic plants of the tropics to the pines of the arctic regions. In some parts, however, the climate is very insalubrious. The humidity of the coasts favouring the putrefaction of a prodigious mass of organic substances, originates diseases which attack Europeans and others not familiarised to the climate; indeed, under the burning sun of the tropics, the unhealthiness of the air is almost invariably a sure indication of extraordinary fertility in the soil. Nevertheless, with the exception of some sea-ports, and a few deep and humid valleys, where the natives suffer from intermittent fever, Mexico ought upon the whole to be considered as a singularly healthy country.

Vegetable productions.

The VEGETABLE PRODUCTIONS of New Spain are infinitely various; and not only are fruits of the most opposite regions assembled there, but they may be frequently met with in singular approximation. From this circumstance, it is nearly impossible to assign to any given article, a particular parallel of latitude, or district of country; and the simplest mode of conveying an idea of the agricultural wealth of Mexico will be to give some account of its most important productions, mentioning the characteristics of each, and the localities where its cultivation has been carried to the greatest extent.

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Maize.

Those which are essential to the subsistence of the inhabitants, first demand our attention; and amongst the most important of these is maize, or Indian corn. This valuable grain is almost every where cultivated with success; and in some favourable spots its fecundity is almost incredible, eight hundred fanegas for one sown, having occasionally been obtained. Its growth is more colossal on the low hot grounds on the coast, and on the slope of the Cordillera, than on the table-land. Wherever irrigation is practicable, from three to four hundred for one, is the ordinary ratio of increase; but where the crop depends upon the season, it is more variable, and in some parts, one good year in ten is all that is expected, the intervening years producing only forty or fifty bushels for one sown. Maize flour is used for food in various shapes; but the most common mode of preparing it for the table, is the following: After the grain is bruised, by passing over it a long stone, something like a rolling pin, which moves in a hollow trough, composed of basalt or lava, a part of the paste thus formed, is taken out and patted skilfully between the hands until it becomes very thin. The cake is then laid on a smooth plate of iron or flat earthenware, placed over incandescent charcoal, or wood embers, where it is allowed to warm through rather than bake, for great care is taken that it be not at all browned. It is served up hot, and eaten with a pungent sauce composed of chile, (a sort of capsicum,) and tomates. This unfermented, but nutritious bread, is called arepa, or more generally tortillas; and the manner in which it is now made is precisely the same as that practised previously to the conquest of Mexico by the Spaniards. The price of this grain varies with the year and the distance of the place where it is grown, from the principal markets. In the capital it is seldom lower than two dollars the fanega of one hundred and fifty pounds; and when the crop fails, it sometimes rises to three dollars and a half. In the interior about half a dollar is the ordinary price. A considerable portion of the land which was formerly devoted to the cultivation of maize, has been neglected since 1810; the war of the revolution having caused a suspension of labour in the mining districts, where an enormous quantity was used, not only by the miners themselves, but by the mules employed in the works. Those parts now most abundant in maize are the Baxio, or central part of the table-land; the plains of Toluca; the southern and eastern parts of the valley of Mexico itself; the state of La Puebla; and the vicinity of Aguas Calientes. Various kinds of fermented liquors, known by the general denomination of chicha de maiz, are prepared from maize by the Indians. They are all more or less intoxicating, as is the pulque de maiz, or tlaolli, which is composed of the saccharine juice or syrup, extracted by pressure from the stalk. Before the conquest, this syrup was condensed by the natives, and used as sugar.

Wheat and barley.

Oats are little known in Mexico, but the wheat and barley of Europe have been naturalised to the soil. The former succeeds well throughout the table-land; but both in Tierra Caliente, and on the eastern and western slope of the Cordillera the ear does not form. The success of the crop on the table-land depends almost entirely upon the timely commencement of the rainy season; for if dry weather continue beyond the middle of June, unless the grounds can be watered by artificial means, drought destroys the crops of wheat, barley, and maize, notwithstanding the extreme fertility of the soil. The great object of the Mexican farmer, therefore, is irrigation; and in the formation of canals, reservoirs, and the like, vast sums have been expended on the

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principal estates. Whenever these are established, the corn lands are watered twice in the year; and so well is the importance of this process known, that a situation is seldom chosen for a hacienda de trigo, or farm, where a supply of water cannot be obtained. Humboldt gives twenty-five bushels for one, as the average annual produce of the whole of the corn lands of Mexico. In France the maximum ratio of increase would be as ten, and in England probably as twelve to one. The principal corn lands of Mexico, are those of La Peubla, the Baxio, the valley of Mexico, Poanas in Durango, and the Nusscous in California. These are mere spots of cultivation upon so extensive a surface of country; but the portion of soil appropriated to the culture of the *cerealia* is quite sufficient for the demand. Maize and bananas are preferred as articles of food; and, besides, so extremely difficult is the communication between the table-land and the country on either side of it, that the eastern and western coasts can be supplied with flour at a cheaper rate from the United States. The soil of the wheat lands is generally composed of tenacious clay, mixed with basalts and amygdaloids, which are difficult to pulverise, yet such land, when brought into a proper state for the purposes of agriculture, is best adapted for the growth of that plant. Rye and barley are raised at higher elevations than wheat, as they are less liable to be injured by cold; but the minimum height at which the proper temperature can be found for bringing the latter to perfection, has not been ascertained. For cattle, barley is in general use, either mixed with maize or by itself.

The potato

The potato for which Europe is indebted to America, is much cultivated in Mexico. It is not an indigenous plant, but was transported from the mountainous parts of Peru, at a very early period after the conquest of that country. It has been generally asserted, that the potato is a spontaneous production of the Andes; but Humboldt and his companion, Bonpland, who diligently examined the vegetable productions from the fifth degree of north to the twelfth of south latitude, found none in a wild state with nutritive roots. They were led to suppose, however, that in the Andes of Chili potatoes are indigenous. In Mexico, they are cultivated on the highest inhabited lands. The natives preserve them for several years, by exposing them first to the frost and then to the heat of the sun. They grow to a large size, some of those found by Humboldt having measured from twelve to thirteen inches in circumference, and are upon the whole superior in quality to any produced in Europe.

The banana.

The banana is, to the inhabitants of the warm regions, what grain is to the people of the temperate and cold countries. It furnishes them with the principal article of their daily food, and has the merit likewise of producing more nutritious substance in a less space, and with less trouble than any other plant. Humboldt calculates, that one acre of ground planted with the platano arton, is sufficient to support fifty men; whilst an acre of wheat would barely supply the wants of three. Its cultivation requires but little attention; when once the suckens are planted nature does the rest. Within eight months after being set, the banana begins to form clusters, and these may be gathered in the tenth or eleventh month after their growth. When the stalk is cut, some other shoots from it, about two-thirds the height of the parent plant, are left standing, and they bear fruit in about three months thereafter. Thus a plantation is perpetuated, without any other subsequent labour than that of cutting the stalks upon which the fruit has ripened, and occasionally digging and dressing round the roots. The ripe fruit of the banana resembles in appearance the bean pod, but is far larger. When exposed to the sun, it is dried in the same manner as the figs of the south of Europe. The skin then becomes black, and emits a smell resembling that of a smoked ham, in which state it becomes an object of considerable internal traffic. Its taste is agreeable, and it is considered as very wholesome, but the ripe fruit, in its crude state, is found very difficult of digestion by newly-arrived Europeans. The green fruit is frequently cut into slices and dried in the sun, and being thus rendered friable, is reduced to powder, in which state it serves the purposes of flour in many culinary preparations. The facility with which this food is produced, gives it an advantage over every other alimentary substance produced in these regions.

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Manioc or cassava.

In the same temperature which favours the cultivation of the banana, the manioc or cassava is grown, and, like it, is abundantly productive of aliment. There are two kinds of manioc; one, called the sweet, which may be eaten without injury, and the other, the bitter, which is a very active poison in its crude state; but both are made into bread, and the latter is most generally used for that purpose. The root is first dried, then grated, and the juice carefully expressed, by which means a tolerably palatable and wholesome flour is produced. It has the property of keeping for a very long time, and is not liable to be attacked by worms, or other insects. The cultivation of the manioc requires more care than that of the banana, and in some measure resembles that of potatoes; the slips are planted, and in seven or eight months the harvest may be gathered. The consumption of cassava bread in Mexico is not considerable, nor at all likely to increase. Rice is but little cultivated, and not very generally known.

Fruits.

Before the year 1810, the cultivation of the olive was prohibited lest the interest of the mother country should thereby be injured. During the revolution, however, a great number of olive trees were planted, and so favourable is the climate for its growth, and so excellent the oil which they yield, that the importation of that article will soon be rendered unnecessary. The vine was likewise a forbidden fruit during Spanish domination; but as the plant flourishes in many parts of Mexico, the attention of the landed proprietors has been turned to the subject; and there seems little reason to doubt that in course of time a supply of wine sufficient for the wants of the country will be obtained from the native grape. Entire estates on the table-land are devoted to the cultivation of chile or capsicum, and few are more productive, as it constitutes one of the necessaries of life with the Indian and Mestizo population, as well as with the creoles, who use it in great quantities. In addition to the vegetable productions already enumerated, Mexico possesses the yam, which is confined to the Tierra Caliente; tomatas (tomatl) with every variety of garden plants and vegetables. There are abundance of apples, peaches, pears, and other European fruits, together with pines, guavas, chirimoyas, oranges and lemons, limes, plantains, pistachio nuts, melons, and all the usual productions of the tropics.

Maguey.

Mexico has likewise the *maguey*, a species of aloe, from which is distilled the favourite beverage of the lower classes in the central part of the table-land. This spirituous liquor is called octli or pulque, and is little known in Europe. In the plantations the plants are arranged in rows having an interval of two or three yards between each. When the head of the plant throws forth the bundle of central leaves, they are cut off, and a hole is scooped in the stalk, which is covered with the leaves. In this hollow the plant seems to deposit all the juice, which, without the excision, would go to form the flowers. It is a real vegetable spring, running for two or three months, and which may be emptied twice or thrice in the day. The plants are extremely productive; indeed a single one will yield annually one hundred and fifty quarts of honey as it is called. It is placed in a situation to ferment, an operation which takes place in a few days, when it becomes fit to be drunk, and is then called *pulque*. In its taste it is said to resemble cider, but it has a most disgusting smell, which, for a long time, prevents Europeans from tasting it. When accustomed to it, however, people become very fond of it, and account it healthy and nutritive. The cultivation of the plant which produces this liquor is of vast

Statistics. importance, both to the public revenue and to the comfort of individuals. It pays a duty on its introduction into the towns; and in the year 1793 the amount of the tax produced at the gates of the cities of Mexico, Toluca, and Puebla, amounted to nearly L.200,000 sterling. By the distillation of pulque, an intoxicating kind of brandy is produced, which is very extensively consumed. The plant from which the pulque is made is also adapted to other valuable purposes. It is used in making ropes, and even paper; it furnishes the inhabitants with a thread, which is called pita; its juice is used as a caustic application for wounds; and its prickles serve the Indians for needles and pins. In the states of La Puebla, Mexico, Guanajuato, and a small portion of Valladolid, are found the principal plantations of maguey. The most celebrated are those in the vicinity of Cholula and in the Llanos de Apam and in the valley of Toluca; but in general, although the plant is found wild in every part of Mexico, no attempt to extract pulque from it is made, excepting in the districts which are within reach of the two great towns of La Puebla and Mexico.

Sugar. Of those productions which in Europe are termed colonial, Mexico supplies sugar, coffee, tobacco, indigo, chocolate, and cotton, besides vanilla and cochineal, of which nature seems to have given to New Spain the almost exclusive possession. Sugar might be raised to almost any extent, the soil in many parts being remarkably favourable to its growth; but the plantations are at present almost entirely confined to the valleys of Cuantla and Cuernavaca, which are situated within twenty leagues of the capital. Humboldt has endeavoured to determine the maximum height at which the cane may be cultivated in Mexico; and although there are almost insuperable obstacles to the establishing of any general theory, it appears to be very generally admitted, that the produce of a plantation on the coast is superior both in quantity and quality to one of similar extent in a valley on the table-land. The same enlightened traveller states that a hectare of the best land in the province of Vera Cruz produces five thousand six hundred pounds of raw sugar, or exactly double the quantity obtained from the same space of ground in the island of Cuba; from which circumstance the extraordinary fertility of the soil may be inferred. The home consumption is enormous, and enough is hardly grown to supply it. The total produce is not exactly known, but it is considerably less than that of the best years before the revolution, owing to the plantations of Oaxaca, the Baxio, Valladolid, and Guadalaxara, having been destroyed during the sanguinary contest for independence. The cane is planted much closer than is customary in Jamaica, but the ground is nevertheless not exhausted by this system; for the extent of his estate enables the farmer to plant only one-fourth of it annually, allowing the other three-fourths to lie fallow until their turn comes round. The sugar of Mexico abounds in saccharine matter, but has a coarse dirty appearance, the art of refining being seldom carried beyond the first stage of the process. From the molasses a considerable quantity of rum is annually distilled, and the trade is considered as a very lucrative one. Any very rapid extension of the cultivation of sugar in Mexico is not to be anticipated, on account of the great expense requisite to construct works on an estate.

Coffee, tobacco, cotton, &c. This, however, forms no drawback to the extensive cultivation of coffee, since the capital requisite to establish a plantation is comparatively small. Many parts of the country are remarkably favourable for the growth of this plant, and the ordinary produce of good land considerably exceeds that of the Havanna. Coffee, however, has never been exported from New Spain, nor has its use been very general in the interior of the country until of late years. In the years 1818 and 1819, large plantations were laid out near Cordova and Orizava, to which constant additions have since been made. The cultivation of coffee possesses at present many advantages over that of sugar; and as the Mexican planters have turned their attention to the subject, there can be little doubt that the European market will ere long draw largely from New Spain additional supplies of this article. The quality of the coffee raised in Mexico is in general excellent; in the opinion of the best judges, it is equal to that of any in the world. Tobacco is a government monopoly, and the growth of the plant is confined to a small district in the vicinity of Orizava and Cordova; it is therefore not likely to become an article of exportation, and is only interesting to European commerce from the quantity of paper used in the cigar manufactories. The quality of the plant is likewise considered as inferior to that of the Havanna. Indigo is in some parts of Mexico a natural production of the soil; but from the preference which is given in Europe to the indigo of Guatemala, and the failure of the native cotton manufactures, its culture has been much neglected. A little is grown on the western coasts, in Yucutan and in Tabasco, and recently it has been introduced on a small scale into the valley of Cuantla. The use of this plant was general amongst the Aztecs previously to the conquest. Cotton was likewise found by the Spaniards amongst the indigenous productions of Mexico, and formed almost the only clothing used by the natives. Its cultivation has since been much neglected; the art of imparting to the cloth the brilliant colours of the Aztecs has been lost; and manufactures are gradually disappearing. Still, however, the raw material might constitute a valuable article of exportation if not of home consumption. The hot country is remarkably favourable to the growth of the plant; and it requires but little attention upon the part of the proprietor. The chief plantations are on the western coast, and in the vicinity of the river Nazas in Durango, whence the cotton-spinners of Zacatecas, Saltillo, and San Luis, are supplied with raw material for their tapalos or shawls, and other domestic manufactures. Cacao, from which chocolate is made, is, like indigo, supposed to have been an indigenous plant; but comparatively little attention is paid to its cultivation. The principal plantations are near Coluna, on the western coast, in the isthmus of Tehuantepec, and in the state of Tabasco, where it forms an article of considerable importance. The number of trees under cultivation is not known, but the average annual produce is estimated at about fifteen thousand cargoes of sixty pounds each.

Drugs. Several valuable drugs are produced in Mexico, as sarsaparilla, jalap, vanilla, snakeroot, and some others, which, however important to the healing art, are of too little consequence to the agriculture or the commerce of the country to deserve detailed notices. Cochineal is, however, a product hitherto exclusively Mexican, and deserves some attention. It was certainly cultivated long before America was known to Europeans. The cultivation of cochineal is at present limited to the intendancy of Oaxaca. There are two species of cochineal, called *grana fina* and *grana silvestria;* one the wild, and the other, if we may be allowed the term, the mesticated kind. The wild is found in several parts of the world, but although pains have been taken to introduce the better kind in many countries, they have hitherto been unsuccessful. The wild cochineal is covered with a cottony down, which prevents the rings on its back from being visible; the fine is distinguished by its being covered with a mealy kind of white powder, which does not conceal the wrinkles on its back.[1]

Wax. The great consumption of wax in the church ceremonies renders this an article of much importance. Some attention is paid to it in the peninsula of Yucutan, where there are colmenares containing six and seven hundred hives; but still a large quantity is imported principally through New Orleans. In addition to the productions already enumerated, Mexi-

[1] For an account of the cochineal insect, see the article ENTOMOLOGY, vol. ix. p. 207, 208.

Statistics. co possesses Tabascan pepper, which grows wild throughout the state of Tabasco, and is collected in the months of July and August. Campeche logwood, mahogany equal to that of San Domingo or Cuba, and a thousand other varieties of timber of the most beautiful and variegated kinds, as also of fruit trees, shrubs and flowers, abound in this country; but the enumeration of these different productions would only be a dry nomenclature of botanical names.

Observations of Ward on the agriculture of Mexico.

"The total agricultural produce of Mexico," says Mr. Ward, "calculated by Humboldt upon the tithes, on a term of ten years, with an allowance of three millions of dollars for the cochineal, vanilla, sarsaparilla, jalap, and Tabascan pepper, which paid no tithes, and two millions more for the sugar and indigo, upon which the clergy only received a duty of four per cent. was found to amount to twenty-nine millions of dollars, and thus to exceed by four millions the annual average produce of the mines, from which the wealth of the country was supposed to be principally derived. Of the present amount it is impossible to form any correct estimate, from the state of disorganization into which both church and state have been thrown by the civil war. But the produce under less favourable circumstances cannot be objected to as a criterion of what may again be; and should the country continue in a state of tranquillity, I am inclined to think that before the year 1835, the agricultural wealth of New Spain will be fully equal to that of 1803." The same able writer then states, as the results of his observation, "that Mexico possesses the means of maintaining in abundance a population infinitely superior to the present number of its inhabitants; that although from the peculiar structure of the country, the agricultural wealth of the table-land is not likely to be brought into the European market, it ensures the general prosperity of the interior, while the cotton, coffee, sugar, indigo, cacao, and other productions of the coasts, will form in the course of a few years a very considerable mass of exportable commodities; that these, in conjunction with cochineal and the precious metals, must render the external trade of New Spain highly interesting to Europe, while the amount of the population, and the absence of manufactures, give to the internal consumption of the country, an importance which none of the other new states of America possess. Mexico," he adds, "contains nearly one half of the seventeen millions of inhabitants that are said to compose the population of the former colonies of Spain; and this half possesses, perhaps, the largest share of the mineral and vegetable riches of the New World. It is not, therefore, a mere theory to suppose that the progress of such a country must exercise a considerable influence upon the manufacturing industry of the Old World."[1] Ten years have elapsed since these observations were written; and although from the distracted state in which the country has ever since continued, the hopes therein expressed have not been realized, yet when the re-establishment of internal tranquillity shall permit native industry to develop the almost boundless resources of the country, there can be little doubt that the agriculture of Mexico will rapidly extend itself, and acquire all the importance which it is calculated to attain in so favoured a region.

Zoology.

Zoology.—The zoology of these interesting regions has only been partially explored, and the gleanings which have been made relate chiefly to ornithology. Of one hundred and thirteen species of land birds, hitherto ascertained to be natives of Mexico, sixty-eight appear to be peculiar to that country, eleven are also natives of South America, and thirty-four of North America. The water birds which have been examined possess no novelty, the whole being identified with the species distributed generally over North America. Amongst the wading birds are two very beautiful species of tiger bitterns, hitherto unknown to naturalists, and as yet not regularly described. The quadrupeds, insects, &c., are too little known to admit of any satisfactory account being given of them. The only quadrupeds yet brought to Europe, are a new lynx, the Canadian porcupine, two small monkeys, and a small tiger cat. Deer and antelopes of some unknown species are found on the table-land, whilst the bison in vast herds ranges throughout some parts of the Mexican territory. Statistics.

Few countries are richer than Mexico in domestic animals of every kind. The horned cattle, sheep, pigs, goats, and horses, introduced by the Spaniards, have flourished in every part of her territory, and multiplied to such a degree that their numbers are now incalculable. In Texas, California, and the Indian country, vast herds run wild in the forests; and even in the interior the number both of horses and cattle kept upon many of the large haciendas is hardly known. The wool of the Mexican sheep is supposed to be of inferior quality; but Mr. Ward is inclined to attribute its defects more to neglect, and the great abundance of the *cactus* and other thorny shrubs in the plains where the great flocks of the interior are fed, than to any peculiarity in the climate. Wherever due attention is paid to preserve the fleece from injury the quality improves and the price rises. Mules are very abundant particularly in the mining districts.

Mines.

Mines.—The mines of gold and silver form the prime objects which have associated the idea of boundless wealth and indefinite splendour with the name of Mexico. The lustre of the precious metals has, by a natural illusion, always dazzled the eyes of mankind, and given a factitious importance to the countries where they are found in the greatest abundance. Gold is far more plentiful in Peru; but, since they were first wrought, the mines of Mexico have produced more silver than all the rest of the world united. The ore is far from being rich; but it is found in vast quantities, in the very finest and healthiest parts of the country, and can be obtained with comparatively little difficulty. Prior to the year 1810, the country was supposed to contain five hundred reales or spots, in which mines were worked, with from three to five thousand mines large and small, included in thirty-seven mining districts, into which the viceroyalty was divided by the government of the mother country. But these were confined to a comparatively narrow circle; for the immense mass of silver which the country has yielded since the conquest, and which was calculated by Humboldt in the year 1803, at 1,767,952,000 dollars, has proceeded from a few central spots of the table-land, in which the capital and activity of the first speculators found ample employment. Yet, three centuries of constant productiveness have been insufficient to exhaust the principal mines originally worked; whilst by far the largest proportion of the great veins still remains unexplored. The principal mines are situated in the provinces of Mexico, Guadalaxara, Guanajuato, Durango, Zacatecas, Chihuahua, San Luis Potosi, Sonora, and Senaloa. Previously to the revolution, the produce of the mines continued to increase; but during the dreadful civil convulsions which have agitated the country since the year 1810, it has greatly declined, and many of the mines have been allowed to go to ruin. From facts which he was at great pains to collect and investigate, Mr. Ward concludes, first, that the annual average produce of the mines before the revolution, amounted to twenty-four millions of dollars, and the average exports to twenty-two millions; and, secondly, that since the revolution, the produce has been reduced to eleven millions of dollars, whilst the exports in specie have averaged 13,587,052 dollars annually. These results were deduced from data furnished in the year 1825. The descrepancy between the produce and the specie exported, is to be attributed to the removal of Spanish wealth, during the revolutionary war, to places of greater security.

[1] Ward's *Mexico* in 1827, vol. i. p. 67. Second edition, London, 1829.

Statistics.

Extraordinary efforts have, within the last ten years, been made by British capitalists to recommence the working and extend the produce of the mines. During the period of excited speculation in 1825, numerous companies were constituted for this purpose, and their shares sold for some time at advancing premiums. There were also two North American and one German association, but on a smaller scale than the English companies. The hopes held out by the projectors have not as yet been realized; but there is reason to believe that, in a little time, the capitals invested in these undertakings will become productive. Although the mines of Mexico are no longer the same source of wealth which they formerly were, the greatest impediments were removed at the revolution. First, the duty upon silver and gold was reduced from ten to three per cent.; secondly, quicksilver for amalgamation was made duty free; and, thirdly, several local mints were established. It must likewise be kept in view, that any falling off that has taken place in the produce of the mines has not arisen from exhaustion; for even in those which have been worked for centuries, no defalcation is observable. Besides, the states of Durango, Sonora, Chihuahua, and Senola, contain an infinity of mines hitherto but little known, and holding out, whenever they have been tried, a promise of riches superior to any thing that Mexico has yet produced. The ores appear to increase in riches the farther north the operations are prosecuted. So much so is this the case, that in the real, or district of Jesus Maria, in that great branch of the Sierra Madre which separates the states of Durango and Chihuahua, from those of Sonora and Senaloa to the north and west, the ores of the mine of Santa Juliana, which does not exceed seventy yards in depth, average seven and eight marcs of silver per cargo of 300lbs, which is the average produce of ten cargos of good ore in Guanajuato; whilst ores of the best quality yield as much as from four to ten marcs per arroba of 25lbs, or forty marcs per cargo. Without entering into similar details respecting each of the other mines in the northern districts, it is sufficient to state, that, with some few exceptions, they all possess in a greater or less degree the same advantages, richness of ores, and veins productive almost at the surface; that few have been worked to any extent; and that, consequently, the risk of making the necessary experiments there is trifling, in comparison of the immense outlay required by the old mines of the southern districts, which have in general attained an enormous depth.

It is a very great advantage to the mines of Mexico, that, unlike those of South America, they are found in regions of moderate elevation and temperature. The greater proportion of the most valuable are at the height of from six to ten thousand feet above the level of the ocean, and, consequently, are exempt from that severity of cold which is found so injurious in Peru. In consequence of the country around the mines being thus in healthy and fruitful elevations, the great number of labourers which they require easily find subsistence; and whenever an extensive mine flourishes, the concourse of people which it collects creates a market for food, which the uncultivated fields around them are soon brought to supply; and towns spring up, and land becomes fruitful, where a few years before only uncultivated deserts were to be seen. It is from the healthiness of the climate in which the mines are situated, and from the fertility of the land around them, that Mexico has been enabled to extract so great a quantity of mineral wealth, rather than to the richness of the ore, or to the accessibility of the veins. The mines are all worked by freemen, compulsory labour being unknown in Mexico. But the miners lead a very wandering and desultory life. There are particular tribes of natives who have been miners from generation to generation, and who lead a roving life, migrating with their wives and children from one district to another, as they are attracted by the fame of superior riches. They are paid by partido, that is, by a share in the ore raised, which is preferred to regular wages however high. It was by employing liberally this powerful stimulus to exertion, that the old Spaniards found means to create a population in the most distant and desolate districts, without having recourse to the mita or tauda, which in Peru and Chili, was in such general use. The natives, far from looking upon mining with repugnance, have a very great love for it, and, in some places, look down with contempt upon those engaged in agriculture. It only remains to be stated regarding the mines of Mexico generally, that their importance consists not merely in the amount of the mineral treasures which they produce, but in the impulse communicated by them to all the other great interests of the country. Agriculture in particular, can only be said to flourish to its full extent in those districts where mining operations are vigorously carried on; for in these places the population is found most dense, and in them, also, exists the greatest demand for the products of the soil.

Statistics.

The following statement of the value of gold and silver raised in Mexico, in the two periods of twenty years, from 1790 to 1809 inclusive, and from 1810 to 1829 inclusive, is derived from the returns of the British consular agent.

	Gold.	Silver.	Total.
From 1790 to 1809...	£4,523,378	£94,429,303	£98,952,681
... 1810 to 1829...	1,913,075	45,388,729	47,301,804

The annexed statement derived from the same sources as the preceding, shews the comparative increase or decrease in periods of ten years.

	Gold.	Silver.	Total.
From 1790 to 1799...	£2,093,170	£47,788,102	£49,881,272
... 1800 to 1809...	2,430,208	46,641,201	49,071,409
Being, as compared with the first period,	an increase of $16\frac{1}{10}$.	a decrease of $2\frac{2}{3}$.	a decrease of $1\frac{3}{5}$.
From 1810 to 1819...	£1,466,830	£24,577,764	£26,044,594
Being, as compared with the first period,	a decrease of 30.	a decrease of $48\frac{3}{5}$.	a decrease of $57\frac{2}{5}$.
From 1820 to 1829...	£446,245	£20,810,965	£21,257,210
Being, as compared with the first period,	a decrease of $78\frac{7}{10}$.	a decrease of $56\frac{2}{3}$.	a decrease of $57\frac{2}{5}$.[1]

The following is a general table of the total coinage of all the mints of Mexico, including that of the capital, from the year 1733, when it was first placed under the direction of the government, and returns of the coinage regularly kept. By this it will appear that the sum of 1,435,658,611 dollars has been *registered* as the produce of the mines of Mexico, in ninety-three years, from 1733 to June 1826.

Coinage of Mexico.

The mint of the capital was established in 1525. Until the year 1733, when it was placed under the direction of the government, there are no returns.

From 1733 to June 1826, the registered coinage is

		Dollars.		
In gold,..... 63,365,406 In silver,.....1,318,853,130		1,382,218,536	3	0
Guanajuato.—From Dec. 1812, to May 15, 1813,	311,125			
From April 1821, to June 1826,.....	2,713,069	3,024,194	0	0
Zacatecas.—From Nov. 24, 1810, to June 1826,.....		32,108,185	1	6
Guadalaxara.—From 1812 to June 1826,				
In gold,..... 225,632 0 0 In silver,....5,433,527 7 9		5,659,159	7	9
Carried forward.				

[1] Parliamentary Paper, session 1833.

Statistics.

Brought forward.			
Durango.—From 1811 to June 1826,	7,483,626	4	0
Chihuahua.—From 1811 to 1814, when the mint was suppressed,.....	3,603,660	0	0
Sombrerete.—From Oct. 1810 to July 16, 1811, when the mint was suppressed,.....	1,561,249	2	0
Total,.....	1,435,658,611	2	3

The total quantity of gold and silver coined in the different Mexican mints during the four years ending with 1829, was,

	Dollars.		Dollars.
In 1826...	8,608,278	1828...	9,982,905
1827...	10,619,217	1829...	11,787,133[1]

When the internal tranquillity of Mexico is restored, and those enterprising individuals who have undertaken to excavate the mineral riches of the country are permitted to prosecute their operations without molestation, a large increase of produce may fairly be anticipated.

Besides the precious metals, gold and silver, which we have thus far exclusively considered, Mexico abounds in other ores, which equally contribute to the improvement and comfort of man in the social state. Iron is found in great abundance in the intendancies of Valladolid, Zacatecas, and Guadalaxara, and especially in the more northern provinces. The increased production of these mines is always suspended by a return of peace, however much they may have yielded in the preceding periods of war. The difference of price in war and peace, both in iron and steel, is enormous. The former has sometimes risen from twenty to two hundred and forty dollars the quintal; and the latter, which in peace is commonly sold for £3, has been known in war to bring £50. During the early part of the wars occasioned by the French Revolution, the tribunal of mines advanced money to the iron miners; but the works were suspended by the peace of Amiens. When war recommenced, these mines were resumed, but very imperfectly, and the tribunal having lent its capital to the government, could not afford them any assistance.

Copper is found in a native state in the intendancy of Valladolid, and also to some extent in Guanajuato. Tin, although obtained in mines, is principally extracted from the earth washed down in the deep ravines. A combination of these two metals, both of which were known to the ancient Mexicans, although they had not discovered iron, was used to form their tools and weapons. By an examination of one of their implements, it was ascertained by some French chemists that they had acquired the art of tempering these two metals, so as to render them equal in effective utility to iron, nay even to steel. Lead is found, but the mines are very little worked. Zinc, under the form of a brown and black *blende*, is obtained in several veins. Antimony is produced in Catorce; and arsenic, combined with sulphur, has been extracted from the minerals found in Zimapan. Neither cobalt nor manganese has yet been discovered in Mexico; indeed these minerals appear to be much less abundant in the equinoctial regions of America than in the temperate climates of the old continent.

Having thus described the various productions of Mexico, vegetable and mineral, we now proceed to give some account of the trade and commerce of the country, the revenue, the army and navy, the state of religion, and other subjects. But as these were materially affected by the political changes which took place in the year 1824, it will be necessary, first of all, to explain the actual form and constitution of the government.

Government.

GOVERNMENT.—When the resignation of Iturbide left the representatives of Mexico at liberty to chuse a form of government, that of a Federal Republic was fixed upon. The Constitution is dated the 4th of October 1824; and by it, whilst each member of the federation is permitted to manage its own affairs, the whole are cemented into one body politic by certain fundamental and constituent laws. This instrument, after declaring the absolute independence of the country, and adopting the Roman Catholic religion, proceeds to enumerate alphabetically the nineteen states of which the republic is composed. These are Chiapas, Chihuahua, Cohahuila and Texas, Durango, Guanajuato, Mexico, Mechoacan (Valladolid), New Leon, Oajaca, Puebla de los Angeles, Queretaro, San Luis Potosi, Sonora and Sinaloa, Tabasco, Las Tamaulipas, Vera Cruz, Xalisco (Guadalajara), Yucatan, and Zacatecas, together with the territories of Old and New California, Colima, New Mexico, and Tlascala. The powers of the supreme government are then divided into three branches; namely, legislative, executive, and judiciary. The legislative power is vested in a Congress, which is divided into two chambers; the house of representatives, and the senate. Representatives are elected by the citizens of the states for a term of two years; one member being returned for each eighty thousand inhabitants, as well as for each fraction that exceeds forty thousand. Thus a state with a population of two hundred and five thousand would return the same number of deputies as one with two hundred and forty thousand. A deputy must be twenty-five years of age, and have resided two years in the state by which he is elected. He must be a Mexican by birth, or if not he must have resided eight years in the republic, and possess landed property to the amount of eight thousand dollars, or have some profession by which he realizes one thousand annually. There are a few exceptions, though too unimportant to require being enumerated.

Certain individuals cannot serve as deputies for the states or territories in which they exercise their functions. These are, persons deprived of the rights of citizenship, or whose civil rights have been suspended; the president, vice-president, and members of the supreme court of justice; the secretaries of state, and those engaged in their several departments; those employed in the treasury whose functions extend over the whole federation; governors of states and territories, commandants-general, archbishops and bishops, governors of archbishoprics and bishoprics, provisors and vicars-general, circuit judges, and commissaries-general of finance and war. The senate is composed of two senators for each state, elected by a plurality of votes in the state legislature or congress. The last of the two named is replaced by a new appointment at the end of two years, the first retaining his seat for four. Both must be thirty years of age, and possess all the qualifications requisite for a deputy. The Congress meets every year on the first of January, and closes its session on the 15th of April, unless it be found necessary to prolong it for a month. An extraordinary congress may be convoked, but sessions can in no case be opened without the presence of more than half the total number of members. The president and other high officers of state are amenable for their conduct to either of the chambers, which can resolve itself into a grand jury; and if two-thirds of the body decide upon an impeachment, the person accused may be suspended from his employment. Both deputies and senators are inviolable, and cannot at any time be called to account for their opinions. A yearly salary of two thousand dollars is assigned to each of them. Both chambers must concur before any legal enactment can be transmitted to the president, who in all cases must yield to a second remonstrance by two-thirds of the members of both houses. Laws of every kind may originate without distinction in either chamber; with the exception of those on taxes and contributions, which must be proposed by the representatives. The

[1] Parliamentary Paper, No. 338, session 1833.

Statistics. sanction of a majority of the members of both chambers is required before a law can be passed. The powers of Congress are very considerable, extending to matters of war, and peace, trade, national improvements, religion, education, the press, the internal administration of territories, taxes, duties, maintenance of the union, finance, expenditure, and the public business of the country.

The supreme executive power is placed in the hands of a president, assisted by a vice-president, who, in cases of any moral or physical disqualification upon the part of the president, succeeds to all his prerogatives, and exercises all his functions. The president cannot be re-elected till after the lapse of four years. The election is made by the congresses of the states, on the first of September of the year preceding the installation of a new president. His powers may be said generally to consist in sanctioning and carrying into effect the decrees and measures agreed upon by the chambers. Under certain legal restrictions he makes all government appointments whether civil, military, judicial, or religious. He assigns military pensions according to law, disposes of the armed force of the country, receives foreign ministers, superintends the administration of justice, suspends government officers guilty of disobedience or infraction of the laws, and concedes or denies his *pase*, or *exequator*, to all decrees of councils, pontifical bulls, briefs, and rescripts, with the consent of the general Congress, if they contain general regulations, and with that of the senate, the council of state, or the supreme court of justice, in cases of a more private and individual character. There are restrictions upon his powers, by which any arbitrary or tyrannical proceedings, or any neglect of duty upon his part, are provided against.

The council of the government exists and acts only during the intervals between the sessions of the Congress, and is composed of one half of the senate, with the vice-president of the republic at its head. Its principal duties are, to watch over the observance of the federal act, and the general laws of the union; to consult with the president, and suggest alterations to him; to convoke Congress in an extraordinary session; to give its consent to various measures and acts of the president; and to act in certain cases for the president and vice-president, in the event of their demise, absence, or incapacity. The government is divided into departments, at the head of each of which is a secretary of state, who becomes responsible for all the acts in his department, to which his signature is affixed, and at the commencement of the annual sessions gives in a report of the state of his department, including the budget for the ensuing year. The secretaries must be Mexican citizens by birth.

The judicial power is lodged in a supreme tribunal of justice; and in inferior courts of departments and districts, the number of which is determined by the Congress. The supreme court is composed of eleven judges and one attorney-general, who must all be Mexicans by birth, and thirty-five years of age. They are elected in the same manner as the president, and take cognizance of all differences between two or more states of the federation, or between individuals of different states respecting grants of land; government contracts; controversies between the inferior tribunals of the federation, or between these and the tribunals of the states; and all impeachments which may be instituted against the president or vice-president, the secretaries of state, the governors of states, or the diplomatic agents and consuls of the republic. They likewise decide all admiralty cases; questions of prize-money, or contraband crimes committed upon the high seas; treason against the nation; and infractions of the constitution, or fundamental laws. They may themselves be called to account, by a tribunal constituted for the purpose by the chamber of representatives.

The tribunals of departments and districts, are composed, the former of a judge and fiscal, and the latter of a judge alone, from whom an appeal lies to the supreme tribunal, in all cases exceeding the value of five hundred dollars. The judges in both instances, are named by the president from a list of three candidates submitted to him by the supreme tribunal. The penalty of infamy can only attach to the person of the culprit. Confiscation of property, judgments by special commission, retrospective laws, and the torture in any shape, or under any pretence, are abolished for ever. No one can be imprisoned without strong grounds of suspicion, nor detained above sixty hours without proof of guilt. No house can be entered, nor papers examined, belonging to any inhabitant of the republic, unless in cases provided for by the law, and then only in the manner prescribed by it. No inhabitant of the republic can be forced to give evidence upon oath, calculated to criminate himself. No one can be deprived of the right to terminate a suit by arbitration, in any stage of the proceedings; nor is it allowable to commence an action without having previously had recourse to the judgment of conciliation.

With respect to the individual states, it was decreed, that the government of each should be divided and organised in a manner similar to that of the federation, and should regulate its own affairs, observe and enforce the laws of the union, protect the liberties of the inhabitants, deliver up criminals reclaimed by other states, contribute towards the liquidation of debts, give an account of receipts and expenditure to the general Congress, and transmit thither a copy of all the decrees and laws which they had passed. It was likewise provided, that no individual state should exact duties, impose new taxes, maintain troops or vessels of war, declare war, or enter into any transaction with foreign powers, not even with other states of the federation, respecting boundaries, or cession of territory, without the consent of the general Congress. In all questions in which the country generally is concerned, such as effecting changes in the constitutional act, the National Congress alone has the power to decide. It may be mentioned, that most of the articles of the federal act are transcripts of corresponding articles in the constitution of the United States. In reference to a point respecting which opinions are at variance, namely, whether a central or a federal republic was best adapted to the habits and tastes of the Mexicans, and the nature of the country, little need be said in this place. It is certain, however, that the same system in its general features, which for nearly half a century has secured tranquillity and prosperity to the United States, has entirely failed to produce the same results in Mexico. But that disturbances would have agitated the country, whatever form of government might have been adopted, seems certain; for they sprung from the ambition of individuals, and the evil spirit of faction, and cannot therefore be traced to the bad working of the federal system. The laws of Mexico are in general mild. There is no imprisonment for debt; but trial by Jury has not yet been established, and bribery is practised to a considerable extent.

Army and Navy.—According to Mr. Ward, the army of Mexico for the year 1827, consisted of 58,955 men, of whom 32,161 were actually under arms; the remainder being ready to be called out if their services should be required. The troops of the line were composed of twelve batallions of infantry, each consisting of eight hundred and twenty-three men, the full war complement being one thousand two hundred and twenty-three; twelve regiments of cavalry, each of five hundred and fifty-nine men, the war complement being eight hundred and fifteen; and three brigades of artillery, of seventeen hundred and sixty-seven men in all. In addition to these, there are twenty-two thousand seven hundred and eighty-eight regular troops under arms, and employed in protecting the northern frontier, or distributed upon different points of the coast. The active militia consisted of nine thousand three hundred and seventy-three men; but this force can be augmented at pleasure to thirty-six thousand one hundred and

Army and navy.

Statistics. sixty-seven men, who have all been enrolled and disciplined to a certain extent, although permitted to retire to their homes when not wanted. A similar regulation was adopted, although to a less extent, with the troops of the line, so that the nominal is considerably greater than the real armed force.

The expenses of the war department for the same year amounted to 9,069,633 dollars, or including the navy, which consisted of one ship of the line, two frigates, a corvette, four brigs of war, a schooner, four gun boats, four launches, and two pilot boats, to 10,378,678 dollars, being about four-fifths of the annual expenditure of the republic. This is an enormous drain upon the exchequer of Mexico; and as no country in the world is better protected from foreign invasion, a reduction of the armed force would greatly add to the national prosperity. This was not only contemplated, but even partially carried into effect. Subsequent events, however, rendered it necessary to increase the army, the present state of which is described in a recent work on Texas. In 1835, the actual army and active militia consisted of 200,000 men, of whom 50,000 formed the federal army, and 150,000 belonged to the states, being supported by them. They are independent of the enrolled militia, which is calculated at 800,000 men, making altogether a force of 1,000,000 men, independently of the Texians. The federal army is furnished by rates from each state; the pay is enormous, and a great source of expence. Each soldier of infantry has one dollar twenty-five cents per day, and the cavalry two dollars; the officers have proportionally large salaries. This makes every one anxious to enter the army. But the soldiers have no rations; they must clothe and feed themselves; the states furnish nothing but arms and ammunition. The horsemen must even provide their own horses; but a horse can be had for from fifteen to twenty-five dollars, and a Mexican soldier can live upon four tortillas a-day. However, this pay is almost always in arrear, being difficult to collect; and soldiers seldom receive any thing but new clothes when they are in rags, and these charged to them at an extravagant rate. As to their food, they are often compelled to borrow, beg, or levy it by military contribution. They are cheered, however, by the love of country and liberty; with the actual privileges which they possess over the peasantry, such as not being amenable to any tribunal except courts-martial; with promises of land, plunder, and the like. The army is altogether liberal, but very turbulent.[1] From other sources we learn, that the regular Mexican soldier is excellent of his kind. He possesses extreme docility, great power of enduring fatigue, considerable personal courage, and extraordinary readiness in acquiring the manual duties of his profession. On the other hand, those who are bad, are intolerably so, and perhaps more difficult to manage than any other class of men in existence.

Mexico possesses only five fortresses, San Juan de Ulloa, Campeche, Perote, Acapulco, and San Blas. The estado-mayor-general, which unites the duties of the quarter-master general's office, with the more scientific branches of the department of engineers, has been occupied since its creation in 1823, in making military surveys, and otherwise taking measures for defending the country against foreign invasion, as well as promoting a knowledge of military tactics.

Ecclesiastical establishments.

Ecclesiastical Establishments. The religion introduced and established in New Spain was that of the church of Rome. In the church as well as in the government, all the highest offices were filled by Spaniards, the situation of parish priest being the only degree of preferment to which a creole could aspire. This accounts for so many of the leaders of the revolution having been clergymen. The secular clergy shared in all the disadvantages under which their creole countrymen laboured, owing to the jealous policy of the mother country; and notwithstanding that the fatal influence which they exercised over the natives had frequently been pointed out to the court of Spain, the old system was persevered in until the year 1820, all benefices being conferred upon Gachupines. The clergy, however, although they took a prominent part in the revolutionary struggle, reaped no immediate advantage from the change. The separation from Spain having broken the link which had connected Mexico with the see of Rome, it was considered as dangerous, hastily to turn out the old Spanish dignitaries, and to supply their places with creoles; and they were, therefore, allowed to remain in undisturbed possession of their preferments. But since the revolution the influence and reverence of the church have been considerably diminished, whilst the old Spaniards have recently been supplanted by creoles. In 1802 the number of ecclesiastics, secular and regular, in New Spain, was estimated at ten thousand, or, including the lay-brothers of convents and other religious houses, thirteen thousand. Their revenues were estimated at 439,000 dollars, besides which they possessed a very large amount of capital in specie, and a portion of landed property. The wealth of the clergy, however, has, from various causes, been materially reduced.

Statistics.

Mr. Ward gives a view of the state of the church in 1827, which he describes as in a very disorganised condition; nor does it appear that matters have much improved since. The republic is divided into one archbishopric, (that of Mexico,) and nine bishoprics; viz. La Puebla, Guadalaxara, Valladolid, Durango, Monterey, Oajaca, Yucatan, Chiapa and Sonora. All these, excepting Sonora, have cathedral churches and chapters, which, with the collegiate chapter of Guadalupe, contain one hundred and eighty-five prebends and canonries formerly in the gift of the king. The country is divided into eleven hundred and ninety-four parishes. In 1827, the secular clergy amounted to 3,677, and their annual income, computing the value of their lands, and capitals at five per cent., and adding to the amount the interest which these produce, the value of their consolidated fund, was estimated at 9,225,015 dollars. Considering the immense extent and population of Mexico, this sum appears moderate. Besides the secular clergy, there are about two thousand monks and nuns distributed in one hundred and fifty convents and nunneries, chiefly of the Dominican, Franciscan, Carmelite, and Augustinian orders. There are also six colleges, containing above three hundred religious, and sixty-one missions. The alms collected in all the convents of Mexico in the year 1826, amounted to 204,000 dollars. "The clergy and monks," says Mr. Edwards, "possess estates, property, and income, to an immense amount, all untaxed. They have also the management of all the *obras pias*, or pious legacies for benevolent purposes, said to amount to 25,000,000 of dollars, mostly lent on mortgages; besides nearly 30,000,000 lent to Spain before the revolution, which became a claim at the peace. The whole army is against the church, and claim their useless property to pay their arrears. The leaders alone, who fear without loving the clergy, have heretofore restrained this feeling, particularly since Santa Anna has glutted them with plunder from another source." It appears that all the Spanish monks and priests had been expelled, their places having been filled by creoles; that the number of nuns was diminishing; and that from the relaxation of religious restraints the monks went wherever they pleased, frequenting gambling houses, theatres, and other places of amusement. "All the clergy," adds Edwards, "are like the army, subject to their own tribunals only, and enjoy many other immunities; there is then a kind of tacit union between church and state. The army and church, although secret foes, find it convenient to support each other."[2] There is little or no religious liberty in Mexico, sects differing from the Catholic faith not being tolerated. There are no

[1] Edwards' *History of Texas*. Cincinnati, 1836.

[2] Ibid.

Statistics. rights or privileges, civil or military, to which any Mexican subject, publicly professing any but the Catholic religion, can be legally entitled. The hold of the church over the Indians was never complete, and it is now fast lessening. They are all more or less inclined to idolatry.

Education. EDUCATION.—Education is as yet at a low ebb, although by the constitution provision was made for the instruction of the people. The Spanish has become the general language of the Mexicans; but many Indians still prefer and retain their own native tongues, and others speak no Spanish; circumstances which must impede the diffusion of knowledge, as only a limited number of books are printed in the Indian languages. According to the regulations of government, all persons should be taught to read and write by the priests, and for this purpose, Lancasterian schools have been established in many parts; but even this elementary education is very much neglected. The sciences in general have not been cultivated to any considerable extent in Mexico, although few governments have expended more in the promotion of physical science, than did that of Spain in America. Three botanical expeditions were sent to Mexico and other parts of its transatlantic dominions, at a cost of upwards of L.80,000. Geometry and astronomy have likewise made considerable progress. Humboldt names three individuals, Velasquez, Gama, and Alzate, who would have held a respectable rank as men of learning, even in Europe. A botanical garden and collections of minerals were formed on a great scale in Mexico. From a school of mines where chemistry and mineralogy were taught, the country derived important advantages; but the revolution gave a severe shock to all these establishments. The new government, however, have taken measures to revive them, which, we trust, will ultimately be successful. The fine arts were also zealously promoted by the old government, which, at an expense of L.8000, transported to Mexico, across the rocky passes of the Cordilleras, a collection of casts of the finest antique statues. There was also an academy of the fine arts which possessed an annual income of L.5000, and by its exertions, many of the public edifices of the capital were adorned.

Manufactures. MANUFACTURES.—The manufactures of Mexico are, and will probably continue for a considerable time to come, in a very rude state. The natives entertain strong prejudices against manual labour, which is for the most part confined to criminals, or persons compelled by debt to engage in it. The Indians excel in working in jewellery, sculpture, carving, and indeed all the ornamental arts; and they are likewise good masons, painters, musicians, &c. They make beautiful vases, similar in form to the Etruscan; besides toys of all kinds, wax figures, feather mantles and mosaics, masks, ornaments, saddles, cotton cloth, ornamented cloths of great value, and the like. They are susceptible of being taught any other handicraft in which ingenuity is necessary to proficiency. All these, however, are disdained by the creoles, who apply themselves merely to agriculture, trade, and the more elegant professions. The manufactures of coarse woollens and cottons, were at one time considerable, but they declined during the revolutionary struggle. Prior to this period, the consumption of these home manufactures amounted, it is supposed, to about ten millions of dollars annually. The importation of European goods was strictly forbidden by Spain, although they could have been procured of a superior quality, at an infinitely lower price. Services of plate worth L.6000 and L.8000 have been manufactured at Mexico; and for elegance and delicacy of workmanship, they rival any thing of the kind produced in Europe. Sugar is made by a complicated process, but at a very cheap rate. The manufacture of glass has also made some progress, and the coaches of Mexico have long been celebrated. Clothing of all kinds is so very dear, that articles of wearing apparel form a good consignment for the Mexican market. French wines have, in a great measure, superseded those of Spain; but, ere long, this article will doubtless constitute one of home manufacture. Statistics.

Commerce. COMMERCE.—The commerce of Mexico does not at all correspond to its great fame for wealth; indeed the smallness of its trade may justly excite surprise. From the time of the conquest until the commencement of the revolution, it was confined to the two ports of Acapulco and Vera Cruz, through which a very limited supply of Chinese and European goods was admitted into Mexico. An exclusive monopoly was enjoyed by a few wealthy houses in the city of Mexico; but in 1778 a relaxation of the old colonial policy took place, and a new impulse was given to commerce. By this change the trade with Europe became concentrated in Vera Cruz, and from the "general balance of trade" kept at this port, the annual amount of the exports and imports may be ascertained. According to Humboldt's estimate for the year 1803, the annual exports consisted of

	Dollars.
Gold and Silver,	17,000,000
Cochineal,	2,000,000
Sugar,	1,300,000
Flour,	300,000
Indigo (native),	280,000
Salt meat,	100,000
Hides,	80,000
Sarsaparilla,	80,000
Vanilla,	60,000
Jalap,	60,000
Soap,	50,000
Campeche Wood,	40,000
Tabascan Peper,	30,000

The total, or 21,780,000 dollars, Humboldt fixes as the average amount of the exports, reckoning by the custom-house registers during several years of peace. The average imports of each year were

	Dollars.
Ropas (linens, cottons, cloths, and silks),	9,200,000
Paper (300,000 reams),	1,000,000
Brandy,	1,000,000
Cacao,	1,000,000
Quicksilver,	650,000
Iron,	600,000
Steel,	200,000
Wine,	700,000
Wax,	300,000
Total,	14,650,000

It is to be observed that this statement refers only to the *registered* articles, or to those upon which the importation and exportation duties were paid. But exclusively of these, the value of the articles clandestinely admitted into the country through the ports on the Gulf, previously to the revolution, was estimated at 4,500,000 dollars a-year; and 2,500,000 dollars were supposed to be annually smuggled out of the country, in plate, bars, and ingots of gold and silver. Notwithstanding all the efforts of government, a regular contraband trade was carried on between Vera Cruz and Jamaica, by which the products of England and Germany were introduced into Mexico.

The trade in registered articles, as estimated by Humboldt, may be stated in round numbers at 37,000,000 dollars annually. But later authorities have reduced it to about 34,000,000, which may be considered as the annual average value in dollars, of the trade of Mexico before the year 1821. The exports always exceeded the imports; and the whole of the exports from Acapulco, and five-sixths of those from Vera Cruz, consisted of the precious metals.

The first effect of the revolution of 1821 was to cause an immediate and extraordinary decrease in the imports and

Statistics. exports, which continued till 1823, when they reached the lowest point of depression, being only 6,259,209 dollars. They gradually rose again, however, and in the year 1824 were as follows:—

	Dollars.
Total imports,.....	12,082,030
Total exports,.....	4,692,557
	16,774,587

But there were, besides, about five thousand tons of shipping employed in 1824 in the trade between Tampico and the United States; and hence if we allow 4,000,000 of dollars for the value of the exports and imports in American bottoms, there will be but little difference between the trade of Mexico in 1824, and its annual value before the declaration of independence. The progress made since that time it is impossible exactly to state; but taking the produce of the custom-houses, along with the number of vessels engaged in the trade, it appears to be very considerable. In 1824 the customs produced 4,351,218 dollars, and the number of vessels which cleared was about 220. In 1826 the customs were nearly doubled, and the number of vessels which entered the ports of Mexico during the same year amounted to 1273. Of the vessels which entered, six hundred and twenty-six were national, and all coasting vessels; ninety-five were English, forty-nine were French, three hundred and ninety-nine belonged to the United States, fifteen to Holland, and about fifty arrived from different ports in South America. The remainder were chiefly from various European ports. Until civil contentions cease, it would be rash to fix the ultimate value of Mexican commerce; yet from the extraordinary resources of the country, it must be regarded as destined to acquire great and lasting importance.

The following is a statement of the trade of Mexico with Great Britain, France, and the United States, (the countries with which she chiefly carries on commercial intercourse,) for the year 1831:—

Great Britain—Official and declared value of exports to,...	£160,751	12	3
Ditto of imports from,...	1,251,768	17	9
France—Exports to valued in francs,.....	8,864,196		
Imports from,.....	20,353,235		
United States—Exports to valued in dollars,.....	5,166,745		
Imports from,.....	6,178,218		

These returns shew a considerable increase, as compared with former years; but it appears small when we consider that, with the exception of the United States, Mexico is the richest and most populous of all the American countries. This originates principally in the want of good ports and large cities on the coast, and the distance and difficulty of the roads from the coast to the table-land, as well as the unsettled state of the country. These circumstances, coupled with the obstacles which the restrictive policy of the Spaniards threw in the way of the importation of foreign products, led to the establishment of manufactures, which at one time were in a very advanced state, and capable of supplying the population with most of the articles required for their consumption. Since the revolution, however, they have declined, and the wealth of the inhabitants has experienced a still greater decrease. It is to be observed, that in estimating the amount of imports before and after the establishment of independence, large allowance must be made for the cheapness at which goods are now valued, compared with their cost in Mexico when trade was little else than a government monopoly.

Tariff. TARIFF.—Foreign vessels pay in the port of Vera Cruz,

	Dols.	Reals.
Tonnage duty and other port charges,.....	2	1
Pilotage on entering,.....	15	4
..... on leaving,.....	19	0

Twenty per cent. is deducted from the duties on all commodities brought from a foreign port in Mexican ships. The Mexican Congress has either very lately modified the tariff, or is about to do so. Vessels of all nations in amity with the republic are allowed to enter the privileged ports, but no foreign ships are permitted to trade coastwise. All articles not specified in the tariff pay a duty of forty per cent. upon the valuation fixed at the port of entry. The articles admitted duty free are, quicksilver, carts of foreign construction, wooden frames for houses, printed books, maps and music, philosophical, mathematical, and optical instruments, slates of all sorts, instruments of agriculture, mining, and artificers, carding wire, plants, and seeds. The articles the importation of which are prohibited, are aniseeds, cummins, and caraways, rum and molasses, sugar, coffee, chocolate, rice, leather, boots, shoes, saddlery, salted and dried meats, lard, wrought wax, tallow, soap, epaulettes, gold and silver lace, galloons, &c., tapes of cotton, shawls of silk or cotton, beds, bedding, copper, lead, biscuit, flour, wheat, vermicella, cotton thread under a certain number, stoneware, trunks, portmanteaus, woollen cloths, parchment, wearing apparel, salt, hats, and tobacco. All articles which are the growth and produce of Mexico may be exported duty-free, excepting gold, in coin or wrought, which pays two per cent. *ad valorem;* and silver, in coin or wrought, which pays three and a half per cent. *ad valorem*. Gold and silver ore, ingots, or dust, are prohibited, under penalty of seizure. Passengers to Mexico must have passports signed by the minister of the republic in Mexico, for which a charge of six dollars is made; and masters of vessels, besides their ship papers and vouchers, must be provided with invoices of shippers, bills of lading, and a bill of health. The monies, weights, and measures are the same as in Spain.

Revenue and finance. REVENUE AND FINANCE.—For information regarding the revenue of Mexico prior to the revolution of 1810, recourse must be had to Humboldt. According to his statements it amounted to 3,000,000 of dollars at the beginning of the eighteenth century. In 1763 it had risen to 5,705,876 dollars, and it continued to increase until 1802, when it amounted to 20,200,000 dollars. This extraordinary rise was owing in part to the establishment of the monopoly of tobacco, but infinitely more to the reduction of the duty on quicksilver from eighty-four to twenty-four dollars the quintal. The principal sources of the revenue at that time were the mines, the monopoly of tobacco, the alcavala or excise upon home-made goods, the Indian capitation tax, the duty on pulque, and the importation and exportation duties. The expenditure might amount to about 10,000,000 of dollars, which may be taken as a fair average for the years immediately preceding the revolution of 1810. Up to this period Mexico had no public debt of any kind. The deficit in the revenue occasioned by the war of independence was supplied by forced loans and new duties and taxes; which, however, were a poor compensation for the loss of the mining duties and the monopoly of tobacco, both of which were reduced to a mere shadow of their former importance. All the war taxes were abolished by Iturbide in 1821; but the distress to which the imperial government was reduced, compelled him again to have recourse to the tax upon houses, which was not definitively suppressed until the year 1823. Forced loans were likwise negociated, and an abortive attempt was made to introduce paper money. The revenues of Mexico now sunk to a low ebb, and continued depressed until the re-organization of the country in 1824. From the report of the minister of finance for 1825, it appears that the income was only 10,690,608 dollars, from which sum was to be deducted the interest of the loans negociated with British capitalists, amounting in all to £6,400,000. The available remainder of Goldsmidt's loan was 1,317,543 dollars, which being deducted from the revenue of 1825, brought it down to 9,373,065 dollars, whilst the expenditure exceeded eight-

Statistics. een millions of dollars. When this appalling statement appeared, it was at first contemplated that the republic would return to the old Spanish prohibitory system; but Congress refused to adopt such arbitrary policy, and after much discussion it was resolved that the old royal monopoly on tobacco should be kept up, under certain modifications. Every branch of the finance department underwent a thorough investigation. Retrenchments were made, and by a series of new and severe regulations, subordination and a proper discharge of duty were enforced. By reductions, and other improvements which were carried into effect, the expenditure in 1827 was reduced to about fourteen millions of dollars, including payment of interest on loans, whilst at the same time the income increased. The revenues of Mexico have been during the years ending the 30th of

	Dollars.		Dollars.
January	1827...13,289,682	January	1830...14,493,189
—	1828...10,494,299	—	1831...18,923,299
—	1829...12,232,385	—	1832...16,413,060

Of these sums about one half was produced by the custom duties. The latter amounted in 1832 to 8,802,920 dollars. During the same year the duties on imported cottons were 1,150,000 dollars, and those on the exportation of the precious metals 309,472 dollars. The total receipts of the custom house of Vera Cruz in 1832, were 2,962,299 dollars, and those of Tampico 1,428,992 dollars. The federal revenue arises from the customs, the mint, monopolies of tobacco, salt, pulque, and gunpowder; lotteries, and privileges; the post-office, stamps, tolls, &c. The monopolies are farmed to ensure the collections. That of tobacco and snuff has lately been granted to English capitalists, who give annually two millions for it. Other branches of revenue are farmed to ensure a steady return; and even the custom-house is reported to be too much under the control of the officers. The state taxes are light and chiefly raised by local monopolies, and excises or tolls in the towns. Land, property, persons, and the church, are entirely exempt from taxation. No country has more need of one or more banks, but such a project is unpopular. The people are afraid of paper money, to which as yet they have not had recourse. The sale of public lands has begun to attract particular attention. Independently of Texas the republic possesses 1,000,000,000 of acres of good land, besides as many of barren soil to dispose of; which, at an assumed rate of forty cents per acre, may realise from three to four hundred millions of dollars. The one half of this land is suitable for raising sugar and cotton, and all useful staples may be cultivated by freemen.

Population. POPULATION.—Before the publication of Humboldt's *Political Essay on the Kingdom of New Spain*, the most erroneous ideas prevailed regarding the population of Mexico. By an actual enumeration made in 1793, in which the returns of two intendancies were made to depend on calculation, it appears that the number of inhabitants were 4,483,529; but for reasons which appear to be satisfactory, Humboldt estimates the total at 5,200,000. The Baron had peculiar advantages in forming an estimate of the population in 1803, when he was in Mexico; and he found the births to be to the deaths in the proportion of 170 to 100; the births to the number of inhabitants as 1 to 17; and the number of deaths to be 1 in 30; whilst in France, which may be considered as the fair average of Europe, the births are to the deaths as 110 to 100; the births as 1 to $28\frac{9}{10}$ths of all the inhabitants, and the deaths as 1 to $30\frac{9}{10}$ths.

The results of his calculations give 6,500,000 as the population in 1803, being an increase of 25 in the 100 in ten years; and the imperfect census of the year 1806, which gives 6,500,000 as the minimum, proves the correctness of his estimate. The civil wars must have materially checked the increase of population, not only by the mortality occasioned on the field of battle, but also by depriving the agricultural population of the means of subsistence. Still, however, their numbers augmented rapidly, and in 1830 they were estimated at 8,666,666. Before the revolution the population was divided into several distinct castes. The classes into which the inhabitants of New Spain are divided is an object of great importance; and upon this subject the diligence of Humboldt has furnished us with ample details. Statistics.

The first class is that of the Europeans, who took up their residence in Mexico, and were called Gachupines by the other inhabitants. They have already been sufficiently described, and their numbers in the country are now comparatively trifling. Europeans.

The next class to the Europeans is that of the unmixed whites, natives of the country, the descendants of the first adventurers who subdued it, or of others, who from time to time have emigrated from the European peninsula. The principal seat of the white population of Mexico is the table-land, towards the centre of which the Indian race is likewise concentrated; whilst the northern frontier is inhabited almost entirely by whites and descendants of whites, before whom it is supposed that the Indian population must have retired at the time of the conquest. It is a remarkable fact, the truth of which cannot be doubted, after the pains taken by Humboldt to verify it, that the proportion of females to males is much greater amongst the creoles than in any of the other gradations of the Mexican population. The creoles are possessed of a very considerable proportion of property in Mexico; the richest mines, and the most fertile tracts of land, and the most productive plantations, are in their hands; and some of them derive revenues from their estates far exceeding those of the most opulent European nobility. The mines in particular have ennobled a large number of creole families. Still, however, the extremes of society meet in this class, many being excessively poor whilst others are enormously rich. The pride of the creoles, an aristocratic feeling founded on their complexion, which gives them distinction, prevents them from pursuing those kinds of labour which are deemed degrading to gentlemen. The consequence is, that their poverty is often even greater than that of the Indians, whilst indolence, added to pride, prevents them from following any employment beyond that of the gaming table, or becoming the flatterers of the richer members of their own class. Creoles.

The Indians form the next class of the Mexican population. They are the unmixed descendants of the aboriginal inhabitants, and consist of various tribes, resembling each other in colour, and in some general characteristics, which seem to announce a common origin, but differing entirely in language, manners, and dress. No less than twenty languages, all different, are known to be spoken in the Mexican territory; and many of these are not dialects, which may be traced to a common root, but differ as entirely as the languages of Sclavonic and Teutonic origin in Europe. Some possess letters which do not exist in others; and in most there is a difference of sound which strikes even the most unpractised ear. The Indians of Mexico are of a darker colour than those of South America, although they live in a climate of lower temperature. They have more beard, and more hair on other parts of the body, than those of the southern continent. They are almost all of them free from personal deformity. Humboldt says of the Indians of Mexico, "I know no race of men who appear more destitute of imagination. When an Indian attains a certain degree of civilization, he displays a great faculty of apprehension, a judicious mind, a natural logic, and a partial disposition to subtilize or seize the finest differences in the comparison of objects. He reasons coolly and orderly, but never manifests that versatility of imagination, that glow of sentiment, and that creative and animating art, which characterize the nations of the south of Europe, and several tribes of African negros." The different nations or tribes are scat- Unmixed Indians.

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tered over a great number of provinces; and they are mostly cultivators, only one tenth being miners, mechanics, fishermen, shepherds, and soldiers. They have several large towns in various provinces; and although some of the tribes lead a wandering life beyond the pale of civilized society, they are gradually becoming blended and identified with the mass of the population. Some of their kings and chiefs, indeed, have obtained high preferment in the federal army. The number of unmixed Indians in New Spain may be estimated at two-fifths of the whole population.

Mixed classes.

The class of mixtures from the primitive races has, in process of time, become a very important portion of the population of New Spain. In a country where rank depends more on the complexion than on those endowments, which, in other countries, confer distinction, it is not surprising, that almost every shade has its limits defined by terms, which, though apparently only expressing the colour, do in reality express the rank of the individual. The son of a white, whether creole or European, by an Indian female, is called Mestizo. His colour is almost a pure white, and his skin is of a peculiar transparency. The small hands and feet, and a certain obliquity of the eyes, are more frequent indications of the mixture of Indian blood than the nature of the hair. If a Mestiza marry a white man, the second generation scarcely differs in anything from the European race. They are generally accounted of a more mild character than the mulattos descended from whites and negresses, who are distinguished by the violence of their passions, and the singular volubility of their tongues. The issue of negros by Indian females bear in Mexico the singular name of Chinos or Chinese, in common language; although by the laws they are denominated Zambos. The term Zambo, however, is generally applied to the descendants of a negro and female mulatto, or a negro and a female Chinese. Another gradation, called *Zambo prieto* or blackish Zambo, is the offspring of a negro and female Zambo. From the union of a white man and a mulatto woman the class of Quarterons is derived. When a female Quarteron marries a white man, the children are denominated Quinteron. The issue of a white man by a female Quinteron is considered as white, and is elevated to the highest rank. Next to the pure Indians, the mestizos are the most numerous caste. It is, however, impossible to ascertain the exact proportion which they bear to the whole population; many of them being included amongst the pure whites, who were estimated before the revolution at 1,200,000, inclusive of from 70,000 to 80,000 Europeans. Of the mulattos and Zambos, and other mixed breeds nothing is known with certainty.

It was the policy of Spain to foster a spirit of rivalry between the different classes of inhabitants, by creating little imaginary shades of superiority amongst them, which prevented any two from having a common interest. Whiteness of skin was the patent of nobility, and even the creole, whom the Spaniard despised, looked with the contempt of a European upon the rest of his countrymen. The revolution, however, put an end to castes, the differences of which were all swallowed up in the grand distinction of Americans and Europeans. The creoles were compelled to court the allegiance of the mixed classes, without whom they could make no effectual head against the Spaniards. Many of the most distinguished characters of the revolutionary war belonged to the mixed breeds; and under the system now established, all are equally entitled to the rights of citizenship, and equally capable of holding the highest dignities of the state. There is neither a pure African population nor a slave in the republic of Mexico.

Antiquities and ancient inhabitants

Antiquities and Ancient Inhabitants.—Of the ancient inhabitants of Mexico, some very interesting monuments remain. The work of Humboldt on New Spain first excited the curiosity of Europeans, and rescued the antiquities of Mexico from the oblivion to which they had so long been consigned; but it was not until recently, that their value as works of art, and as indications of a considerable advance in civilization, was fully appreciated. Pyramids having even a larger base, and being otherwise scarcely inferior in magnitude to those of Egypt, are found in many parts of Mexico. Amongst the most celebrated is that of Cholula, the base of which is one thousand four hundred and twenty-three feet on each side, and the height one hundred and seventy-seven feet. It consists of eight graduated square towers, each rising above the other, and terminating in a species of sanctuary. Here vestiges of noble sculpture are visible, as well as at Otumba, Oaxaca, Mitlan, Tlascola, and Palenque. The ruins of the latter, in particular, have attracted a considerable degree of attention, and are worthy of description. They extend, says Colonel Galindo, of whose description we shall avail ourselves, for more than twenty miles along the summit of the ridge which separates the country of the wild Maya Indians, from the state of Chiapas, and must anciently have embraced a city and its suburbs. The principal buildings are erected on the most prominent heights; and several of them, if not all, have been provided with stone stairs. The principal edifice, which has been sometimes styled the palace, is built in several squares; but the main halls or galleries, run in a direction from the north-north-east, to the south-south-west; and this position has been observed in all the edifices hitherto examined, be their situation what it may. The houses have all been substantially built of stone, cemented with mortar; but symmetry has been little studied in their construction, it is supposed less from ignorance than from design. Other ruins of considerable magnitude, and distinguished by numerous sculptures, are found upon the neighbouring hills. In the vicinity there is one building in particular, apparently a religious edifice, which deserves notice. Two galleries constitute its foundation; the front one occupying its whole length, whilst the back one is divided into three compartments. Of these, the eastern has the appearance of a dungeon; the western is a small room with a chapel ornamented with elegant relievos. These consist of representations of the human figure, in various attitudes, and adorned generally with boughs and feathers. There are other very interesting ruins in this part of Mexico, but they have not as yet been sufficiently described.

The mountain of Tezcoca is nearly covered with ruins of ancient buildings. At Mitlan there are the remains of a large palace, the architecture of which possesses a stately grandeur, and melancholy beauty of a peculiar character. The roof of the portico is supported by plain cylindrical columns, and the façade of the palace is covered with a beautiful matwork, or basket scroll, such as is found in Egyptian sepulchral chambers. Many of the statues found at Otumba, Mitlan, Jochichalo, and the magnificent flower-temple of Oaxaca, are sculptured in a purely classical style whilst vases rivalling those of Egypt and Etruria, have been discovered in sepulchral excavations. Roads are to be met with, not only in the vicinity of great cities, but at a vast distance from them, artificially constructed like the Roman military roads, of large squared blocks of stone. These roads present a continued level, and may be called viaducts, in contradistinction to aqueducts, which were also constructed by the ancient inhabitants of Mexico. Where they traverse acclivities, they are parapeted, and the indications both of regular posting stations at certain intervals, and of the regular division of the distances, upon the principle of the mile-stones of our turnpike roads, may still be observed. Bridges constructed of the same durable materials, and thrown across torrents, are also to be found. In these bridges there is occasionally an approximation to the principle of the arch and keystone; but in general they only display the primitive and obvious form of architraves of stone superimposed

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on two or more piers of the same massy character and durable materials. Every feature of these structures is at once singular, ingenious, and colossal.

With regard to the period at which these remarkable edifices were constructed, and the people to whom the labour is to be attributed, the learned are as yet not agreed. One point, however, seems pretty generally admitted, viz., that their erection must be traced to a race who inhabited the country prior to the invasion of the Mexicans, and who had attained to a considerable degree of civilization. An attempt has been made to prove that this people lived at a time prior even to the Toltecans, who preceded the Mexicans by six hundred years; and a close analogy between the antiquities of Mexico and those of Egypt has been shewn to exist. The hypothesis advanced regarding the people is, that they were a branch of the Anakim or Cyclopean family of Syria, the shepherd kings of Egypt, the Oscans of Etruria, and the Pelasgians of Greece, the Titans or giants of classical romance, and who are recorded to have been severally expelled from Egypt and Syria.

In reference to these questions, an able writer observes: "The first and strongest conviction which will flash on the mind of every ripe antiquarian, whilst surveying the long series of Mexican and Toltecan monuments, preserved in the various works to which we have alluded, is the similarity which the ancient monuments of New Spain bear to the monumental records of ancient Egypt. Whilst surveying them, the glance falls with familiar recognition on similar graduated pyramids; on similar marks of the same primeval Ophite worship; on vestiges of the same triune and solar deity; on planispheres and temples, which, though characterised by some distinctions entirely American, are not less worthy of the notice of the Egyptian antiquarian; on relics of palaces at once noble in their architecture, and beautiful in their proportions and decorations; on monuments sepulchral, domestic, religious, or warlike, which deserve the designation of Cyclopean as much as any that are now extant in Italy or Greece; on idols and sculptures, some of rude and some of finished workmanship, exhibiting different eras of civilization, and often presenting the most striking analogy in posture and gesture to the monumental style of sculpture, and of statuary preeminently called Egyptian. Lastly, the eye of the antiquarian cannot fail to be both attracted and fixed by evidences of the existence of two great branches of the hieroglyphical language; both having striking affinities with the Egyptian, and yet distinguished from it by characteristics perfectly American. One is the picture-writing peculiar to the Mexicans, and which displays several striking traits of assimilation to the anaglyphs, and the historical tablets of the Egyptian temples. The second is a pure hieroglyphical language, to which little attention has been hitherto paid, which appears to have been peculiar to the Toltecans, or some still more ancient nation, that preceded the Mexicans, which was as complete as the Egyptian in its double constituency of a symbolic and phonetic alphabet; and which, as far as we can judge, appears to have rivalled the Egyptian in its completeness, whilst, in some respects, it excelled it in its regularity and beauty."

"The pyramid of Cholulas," says the same writer, "exhibits a most singular identity with the model of the temple of Belus, described by Herodotus, and which, by many scholars, has been considered to be the Scriptural tower of Babel. But in the internal economy of the pyramids, the analogy between those of Egypt and Mexico is still more remarkable. In both, descending galleries, at a particular astronomical angle of declination, lead to central chambers, either for the purpose of mystery or sepulture. Amongst other marks of architectural identity, may be mentioned, those traced amongst the ruins of Palenque, where the well-known Cyclopean arch, consisting of receding steps of stone in a triangular form, is seen, and where a rectangular square is surrounded by cloisters built in this manner, and lighted by windows bearing the exact form of the Egyptian face. With regard to the personal characteristics and costume, the sculptures bring to light a people of a very remarkable appearance. Their physiognomy is unlike that of any of the various families of mankind, that at present inhabit the globe, or have been rendered familiar to us by ancient sculptures. Their receding forehead, their low facial angle, and the conical form of their heads, is quite unique; and the large long nose, the facial line receding in the same singular manner from the base of the nostrils to the termination of the chin, grotesquely broken off by an unsightly protrusion of the under lip, present a physiognomical outline revolting to the European standard of beauty. The costume shows some striking analogies with that of the Egyptians; but there are at the same time differences from it as remarkable. The Egyptian apron, for instance, was different. It was generally of striped cotton, and folded in a peculiar manner; a portion of it forming a girdle and passing between the legs, resembling a similar article of dress worn by the East Indians at the present day. But the Toltecan apron resembles the Roman military apron or the Scotch philabeg. It descends from the waist and covers the thigh down to the knee; it is, however, distinguished by one Egyptian appendage, namely, by the mimic tail of an animal, which appears to have adorned the Toltecan hero, as it adorned the Egyptian demigod. The apron is supported by a baldric, which descends from the right shoulder to the left side, and joins the girdle at the waist. The dress of the military and superior class of Egypt is not to be found in the Toltecan costume, but the following strong resemblances exist: The breast-plate and collar of the Toltecans were sometimes decorated with a symbol of the sun; the armlets, bracelets, and anklets, are strikingly analogous to those of the Egyptian. The legs of the Toltecan heroes, however, are invested with sandals, some of them reaching above the ankle, others like greaves, covering the leg to the knee; whilst others in every respect resemble the Highland sandal. All these parts of dress would appear to have been richly ornamented; and the whole dress, it is said, may be safely described as at once gorgeous and elegant, and in these respects nowise inferior to the Egyptian. The head-dresses, however, are in general extravagantly grotesque, without regularity or taste, although, like the Egyptian, constructed out of certain combinations of symbols."

With respect to the religion and religious rites of this ancient race, a striking analogy with those of Egypt has likewise been traced. The gods of the Toltecans appear sculptured, as usual in bas-relief, in the dark inner rooms of temples. He who would appear to be the chief-god, is portrayed on the inner wall of the adytum of one of the sanctuaries belonging to the great temple of Palenque. He seems to be not only the chief but the sole god, and he is worshipped symbolically under other forms and in other localities. He is supposed to be identical with the Osiris of Egypt and the Adonis of Syria, or the well-known classical combination of both divinities, the ancient god *Adoni-Siris*. The manner in which he is enthroned, the cushion on which he reposes, the cap, the symbols, and various appurtenances, show an analogy with the Egyptian deity. But there is a column affixed to the cap which is not found on any Egyptian head dress; it was, however, an unquestionable symbol of Osiris. "Various characteristics of the worship of Osiris and Adonis, are complete in the sculptured tablets of Mexico. A priestess kneels before the Toltecan god in the attitude of adoration, and offers him a pot of flowers, not the mint offered to Osiris, but the blood-stained hand-plant or *manitas*, which all the monuments attest, was anciently held sacred throughout Mexico. On the sculptured tablet over the head of the divinity, appear, precisely in

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the Egyptian fashion, the phonetic characters of his name, in an oblong square, which in Egypt was devoted to the names of gods. Of the phonetic or symbolic character, however, nothing as yet is known. The same divinity is represented on one of the walls at Palenque, not in a human, but in an animal form. Instead of the hawk of Egypt, however, the Toltecans chose as their sacred bird the rainbow-coloured pheasant of Central America, which is perched on the Toltecan cross, resembling the Christian, and with its lower extremity terminating in a heart-formed spade. The subject of the sculpture shows the simplicity of the worship. Two Toltecan heroes, chiefs, or priests, stand beside the sacred bird; one of them supports an infant in his arms, probably for baptism, which was a rite practised by the votaries of Adonis, and at other places there are indications of a similar ceremony."

Of the temples we have already given a cursory notice. Their architecture has a theological character like that of Egypt and of Greece; and although their forms are peculiar to the country, the original type of them is extant in Syria, Palestine, and Judæa. Like those of the Egyptians, they are all distinguished by architectural peculiarities, exclusively appertaining to the people by whom they were erected. A high-place of three successive terraces or steps, generally constitutes the platform of the temple. The terraces are distinguished by that sloping form which the Egyptian architects peculiarly affected, and they are generally constructed of large blocks of stone, covered with stucco equally hard and durable. On the top of the high-place was an oblong rectangular court; and in the centre of this court stood the temple, divided, like the rock temples of Nubia, into three dark rooms built of stone, and having an ark, or barn-shaped roof. The innermost of these rooms constitutes the sanctuary. The apartments are occasionally decorated with painted sculptures. Sometimes the staircase ascends the high-place in front, traversing the curvilinear terraces in a straight line to the door of the temple. Occasional variety was given to the square form of the area, and to the triple form of the terraces, by staircases ascending to the sanctuary from each of the cardinal points. The high-place has sometimes a circular instead of a square ground plan, and in that case, it may remind antiquarians of the well known *Tepes*, or high-places of Syria, which is a presumptive proof of the Syrian origin of these structures.

The writer already quoted thus speaks of Palenque: "It may be appropriately termed an ecclesiastical city rather than a temple. It seems to be the locality of the chief cathedral church of the Toltecan religion. Within its vast precincts there appear to be contained, a pyramidal tower; various sanctuaries; sepulchres; a small and large quadrangular court, one surrounded, as we have said, by cloisters; subterranean initiatory galleries beneath; oracles, courts of justice, high-places, and cells or dwellings for the various orders of the priests. The whole combination of the buildings is encircled by a quadrilateral pilastered portico, embracing a quadrangular area, and resting on a terraced platform. This platform externally exhibits the same architectural model which we have described as characterizing the single temples. It is composed of three graduated stucco terraces, sloping inwards, at an angle of about seventy degrees, in the form of a truncated pyramid. Four central staircases, one facing each of the cardinal points, ascend these terraces in the middle of each lateral façade of the quadrangle; and four gates fronting the same cardinal points, conduct from the top of each staircase into the body of the building, or into the great court. The great entrance, through a pilastered gateway, fronts the east; and descends by a second flight of steps into the cloistered court. On the various pillasters of the upper terrace are the metopes, with the singular sculptures we have described. On descending the second staircase into the cloistered court, on one side appears the triple pyramidal towers which may be inferred, from the curious distribution of little cells which surround the central room of each story, to have been employed as a place of royal or private sepulture. On another side of the same cloistered court is the detached temple of the chief god, to whom the whole religious building appear to have been devoted; whom we have described as bearing all the characteristics of the Syrian god Adoni-Siris; and who appears to have been the great and only god of the nations, who worshipped in this temple. Beneath the cloisters, entered by well-staircases from above, are what we believe to be the initiatory galleries. These opened into rooms, one of which has a stone couch in it, and others are distinguished by unintelligible apparatus carved in stone. The only symbol described as found within these sacred haunts is, however, perfectly Asiatic, and perfectly intelligible; we mean two contending serpents. The remnant of an altar, or high-place, occupies the centre of the cloistered quadrangle. The rest of the edifice is taken up with courts, palaces, detached temples, open divans, baths, and streets of priestly cells or houses in a greater or less degree of dilapidation."

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It appears that the creed of this ancient people was a form of deism, which permitted some varieties of symbolic representation. From the few records of their religious rites which have come down to us, and which are principally derived from the extraordinary rolls of American papyrus, formed of the prepared fibres of the maguey, on which their beautiful hieroglyphical system is preserved, we learn that they were as simple as their creed. No human nor even animal sacrifices appear to have been offered up to the presiding divinity of their temples; nothing, indeed, but fruits and flowers. Such a religious system was therefore quite different from the hideous idols and sanguinary sacrifices which were in use amongst the Mexican people.

IV. POLITICAL DIVISIONS.

Mexico.

The republic of Mexico, as has already been stated, is divided into nineteen states and five territories, each of which we shall now proceed to give a short account of. Mexico, the most populous of the whole, and which also contains the metropolitan city, extends from 16. 34. to 21. 57. of north latitude, and includes an area of about five thousand square leagues. On its western side above two hundred miles of this state are washed by the South Sea, but no part of it approaches within many miles of the Eastern Ocean. Being situated both on the low and on the high land, it partakes of the climate of each; but more than two-thirds of it are mountainous, and consequently cool and healthy, whilst that part which borders on the South Sea is hot and insalubrious. Only the highest peak of one of its mountains attains the region of perpetual snow, and no other summit but that of Toluca is equal in height to Mont Blanc. The state is divided into eight districts, viz. Acapulco, Cuernavaca, Huijutla, Mexico, Tasco, Toluca, Tula, and Tulancingo. These embrace a large proportion of valuable mines, as well as a number of districts celebrated for the richness of their agricultural produce. Real del Monte, Chico, Capula, Zimapan, San Jose del Oro, El Cardonal, La Pechuga, the Rancho del Oro, Tasco, Tepantitlan, Zacualpan, and Tetela del Rio, are all in the state of Mexico; as are the valleys of Toluca and Cuautla Amilpas, the rich plains of Pachuca, and the fertile Vega of Tulancingo. The best and most valuable portion of this state is what is called the valley of Mexico, a fertile and splendid region variegated with extensive lakes, and surrounded by high volcanic peaks. Its general figure is an oval of about two hundred miles in circumference, and forms the very centre of the great table-land of Anahuac, elevated from six to eight thousand feet above the level of the ocean.

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The most interesting object in the valley of Mexico is the vast system of drainage by which the capital is protected against the periodical inundations of the lake of Tezcuco, which, during the two first centuries after the conquest, threatened it repeatedly with destruction. The valley of Mexico serves as a receptacle for the humidity which filters from every part of the lofty ridge of mountains by which it is environed. Only one stream issues from it, whilst it receives the waters of several rivers, which, accumulating in the immense basin, form the great lakes Tezcuco, Zumpango, San Cristobal, Chalco, and Xochimilco. The city is situated on a lower level than some of these sheets of water, particularly that called Zumpango; and during the rainy season they burst the dykes which separate them, and forming a junction, rush towards the capital, filling the streets which approach nearest to their own level. A rapid succession of misfortunes arising from these inundations compelled the Spanish government to adopt measures for averting the danger. Hydraulic works of immense magnitude were begun in 1607, and have been carrying on almost ever since at a vast expense. Canals were cut, and other artificial means were adopted to convey the waters of the lakes in another direction. The *desague*, or great canal which was constructed to carry off the waters of the lake of Zampango, is of stupendous dimensions, but from the nature of the soil through which it passes, the imperfect manner in which it is executed, and above all, from the lake itself being twenty feet above the level of the great square of Mexico, it would be found but an imperfect security against an inundation, should a very rainy season occur. During the revolution these works were much neglected, nor have they yet been properly finished or put in a good state of repair. In the lake of Chalco there are a number of Chinampas, or what have sometimes been called floating gardens. Whether or not they ever did float is questionable; but it is certain that at present they are all fixtures. They are artificial islands, about fifty or sixty yards long, and not more than four or five wide. They are separated by ditches of three or four yards in breadth, and are formed by taking the soil from the intervening ditch, and throwing it on the Chinampa, by which means the ground is raised generally about a yard, and thus forms a small fertile garden, where the finest culinary vegetables, fruits, and flowers are raised, and from which the markets of the capital are amply supplied.

In the centre of this fine valley stands the city of Mexico, the capital of the republic. The approach to it does not convey a very favourable idea either of the capital or of the country around it. On the Otumba side the valley is destitute of those beautiful features by which it is characterised on the south and east; the receding waters of the great lake of Tezcuco having left a crust of carbonate of soda, by which vegetation has been impaired or destroyed. Sterility prevails almost the whole way from the village of San Juan de Teotihuacan to the convent of Guadalupe, in which is the famous image of the Virgin of Guadalupe, the patroness of Mexico. An avenue extends from this place to the gates of the city, upon the line of one of the ancient causeways. The suburbs of Mexico have a ruinous and desolate appearance, and it is not until the central parts of the city are seen, that the praises bestowed upon it by Humboldt are found to be no exaggeration. The same distinguished traveller is of opinion, that although modern Mexico is three miles from the lake of Tezcuco, and six miles from that of Chalco, it nevertheless occupies the identical site of ancient Mexico, or Tenochtitlan, and that a great part of the waters of the valley have been dried up.

Mexico is undoubtedly the finest city built by Europeans in the western hemisphere. There does not indeed exist a city of the same extent to which it can be compared; since it is equally remarkable for the uniform level of the ground on which it stands, for the regularity and breadth of the streets, and for the extent of the squares and public places. The architecture is generally of a very pure style, and there are even edifices of exceedingly beautiful structure. The streets are not only broad and airy, but of vast extent, some of them extending nearly two miles in a straight line. The houses which are all built of stone, are spacious, and highly ornamented; but they appear low to a European eye, a want of height being complained of as a general defect in Mexican architecture. The roofs are flat, and when seen from an elevation, have the appearance of immense terraces, the parapets by which they are separated being lost in the distance. The streets are all well paved, having pathways on each side. The public buildings are magnificent, and have been constructed at an enormous expense. Nearly at one extremity of the town stands the Alameda, which communicates with the Paseo Nuevo, a broad avenue of trees. This building is a summer palace constructed during the viceroyalty, upon a rock, the foot of which was once washed by the waters of Tezcuco. Its situation is beautiful, and commands a most magnificent view of the valley of Mexico.

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But amongst the monuments of Spanish splendour, the cathedral and the viceregal palace are perhaps the noblest. They are situated in the Plaza Mayor, or great square, and were erected soon after the conquest. The cathedral, which is built upon the site of the great Mexican temple, is spacious, grand, and profusely ornamented. It covers an immense space of ground, and riches have been lavished in ornamenting the interior, without, however, producing a grand or imposing effect. The most remarkable feature is a balustrade, which occupies the centre of the church. It is composed of a metal brought from China, and said to be a composition of brass and silver. In the outer wall is a stone covered with hieroglyphical figures, employed by the Aztecs to designate the months of the year, and which is supposed to have formed a perpetual calendar. At a little distance from it is a second stone, upon which human sacrifices were offered up by the ancient inhabitants of Mexico. The cathedral forms part of the northern side of the square, and another whole side is occupied by the palace; an immense building, formerly the residence of the viceroy, but now converted into government offices. In the interior, the part most worthy of notice is the botanical garden, which was extensive as well as rich, until the period of the revolution, when a portion of it was converted into barracks. It is said to contain many species of plants hitherto but little known in Europe. Besides the cathedral, there are nearly one hundred other churches, ornamented and decorated in the same style of profusion. The college of mines is a magnificent building, but it has settled down in such a manner as to deflect from the perpendicular the spacious rows of columns, windows, and doors. The collection of minerals which the college contains is rich but ill-arranged. The mint is also a fine building; and several of the convents, as well as some private palaces, are of great extent and magnificence. The Acordada, a prison and house of correction, is a very fine and extensive structure, capable of containing twelve hundred inmates. Besides the hospital of San Juan de Dios, there are other buildings appropriated to the reception of the sick poor.

The police of the city is excellent, and the streets are well lighted and kept in good repair. There is no scarcity of water, abundant supplies of which are brought from the lakes by means of aqueducts. Salt is easily procured from the soil near the city, which is impregnated with muriate of soda. All kinds of provisions are brought to the markets in abundance from the surrounding districts, chiefly by Indians, who likewise bring for sale little toys and baskets executed with considerable neatness. The venders of charcoal amuse themselves whilst waiting for customers, by carving little figures of birds and other animals in the commodity which they sell. The leperos, the lowest class of inhabitants, display remark-

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able ingenuity in forming figures of soap, wax, pith of trees, wood, and other materials, which may be purchased for the smallest coin. With regard to the society of Mexico it would be hazardous to offer any opinion. A long civil war, prosecuted with almost unparalleled ferocity, has done much to deteriorate the morals of the people; and it yet remains to be seen what a better system of government can effect for raising in the scale of civilization a race of men composed of the most heterogeneous elements. The population amounts to about one hundred and thirty thousand, of which number from twenty to thirty thousand are leperos, who live in the most wretched and filthy state.

There are a number of other towns in the state of Mexico. Acapulco, on the south-west coast, was once celebrated for its wealth, and is described as a very fine sea-port. It was from this place that the richly-freighted Spanish galleons took their departure to distribute the spoils of the western over the eastern hemisphere. It subsequently sunk into comparative insignificance; but by the recent returns of its customs it appears to have again risen into considerable importance. The population amounts to about five thousand. Zacatula is likewise a good port on the same shore, but it has little trade. Toluca, in the interior, is a considerable town, situated at the foot of two steep barren hills, and distant about twenty-seven miles south-west from the capital. A few miles to the north-west of the city of Mexico is Tezcuco, a town formerly the residence of a tributary Indian prince, but now almost desolate. Amongst other small towns may be mentioned Otumba, once large and flourishing, but now a mere village; Lerma, which is surrounded by an extensive morass, traversed by fine raised causeways; Chalco, a pretty large town, situated in a lake of the same name, about twenty miles to the south-east of the capital; San Augustin, at which a great annual fair is held, frequented by vast multitudes from Mexico; Tacubaya, a village about four miles from the gates of the capital, and formerly the country residence of the bishop of Mexico; Pachuca and Cuyoacan. Besides these places there are a number of haciendas, of which Chapingo is considered as one of the finest specimens in Mexico. It is distant about a league from Tezcuco, and the lands around it are exceedingly rich and well irrigated. The buildings erected to receive the grain are on a magnificent scale, and the vicinity of the capital affording a ready market for the crops, the estate is one of great value. About sixty miles from the metropolis is Cuernavaca, a place of no importance in itself, but deriving interest from the richness of the surrounding district. In the neighbouring valley of Cuautla, stands the town of Cuautla Amilpas, where Morelos made so noble a stand against the royal army. The population of the state of Mexico, according to the census of 1803, amounted to 1,511,800; but as it suffered much during the civil war, and by the new political division of the country lost a portion of its territory, the number of inhabitants at present can scarcely exceed one million. The legislative assembly composed of nineteen deputies, elected in the ratio of one for every fifty thousand inhabitants. The districts are placed under the inspection of prefects and sub-prefects.

Queretaro.

Queretaro.—To the north-west of Mexico is the small state of Queretaro, the territories of which were formerly comprehended in the neighbouring intendancies of Mexico, La Puebla, and Guanajuato. They are now divided into the six *partidos* or districts of Amcalco, Cadereita, San Juan del Rio, San Pedro Toliman, Queretaro, and Xalpan, which contain in all a population of above 200,000. The inhabitants, with the exception of those of the capital, are mostly employed in agriculture. The wool of the sheep is highly prized, but agriculture here is not so important a speculation as it is in other parts of the republic. Queretaro, the capital is divided into five parishes, and contains some fine churches and convents; particularly that of Santa Clara, which is an immense building, said to resemble a little town in the interior, being regularly laid out in streets and plazas. This place has quite the air of a manufacturing town. More than half the houses contain shops, and the population is engaged either in small trades, or in the wool manufactories, which were once very extensive, but fell off in the general decline of manufactures. Woollen cloths, however, are still made here. About two leagues from the town is a great ravine called the Canada, which is inhabited by Indians, and abounds in gardens and magnificent trees. Queretaro contains above forty thousand inhabitants.

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Guanajuato

Guanajuato.—To the westward of Queretaro is Guanajuato, which may be called either a mining or an agricultural state; for the prosperity of the two branches is so closely connected that the one can hardly be said to flourish without the other. Manufactures of wool and cotton formerly abounded in many of the towns, but they have greatly decayed, and the mines, particularly the celebrated one of Valenciana, must now be looked to as the chief source of wealth. The town of Guanajuato, in the vicinity of which the principal mines are situated, contains numerous splendid memorials of the former wealth of its inhabitants. Many of the private dwellings are magnificent, as are the churches, chapels, and other religious edifices. Zelaya is a considerable town containing about ten thousand inhabitants. The town of Irapuato, according to the census of 1825, contains a population of sixteen thousand and fifty-four souls. Some of the public buildings are fine, particularly the convent of nuns, called De la Enseñanza. There are a few cotton-spinners and weavers, but the bulk of the population consists of agriculturalists who reside in the town and have estates in its vicinity. Salamanca is likewise a considerable place, situated in a rich part of the country. The state of Guanajuato contains, according to the census of 1825, a registered population of 382,829 souls; but this was supposed to be incorrect and the number of the inhabitants may now be more correctly estimated at 500,000.

Guadalaxara or Jalisco.

Guadalaxara or Jalisco.—To the westward of Guanajuato stretches out the large state of Guadalaxara or Jalisco. Like all other states of Mexico, its shape is very irregular, but it is computed to contain nine thousand six hundred and twelve square leagues, and it extends one hundred twenty-three leagues along the shores of the Pacific. It is divided into eight districts, viz. Guadalaxara, Lagos, La Barea, Sayula, Etzatlan, Tutlan, Tepec, and Colotlan; and these again are subdivided into twenty-six departments, containing in all three hundred and eighteen pueblos, three hundred and eighty-seven haciendas, and two thousand five hundred and thirty-four ranchos, with a registered population in 1825 of 656,830 souls. Before the separation of the district of Colima, Jalisco contained eight hundred thousand inhabitants. The capital which bears the same name is reckoned the second city of the republic. It is built with great regularity, the streets running at right angles, being well paved, and having raised pathways on each side. The houses, with the exception of those in the suburbs, are finely built. There are fourteen squares, twelve fountains, and a number of convents and churches, the principal of which, the cathedral, is still a magnificent building, although it suffered severely in an earthquake which occurred in 1818. The Alameda or public walk is very prettily laid out, with a fountain in the centre, and a stream of water all round. Within the town, the Portales de Comercio, erected on every side of those immense squares of houses, are the principal rendezvous; as, besides a number of handsome shops well provided with European and Chinese manufactures, they contain a number of stalls covered with a great variety of domestic productions. Considerable quantities of shawls of striped calico were formerly made here; but these home manufactures have been superseded by importations from the United States. Guadalaxara derives little benefit from

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its foreign trade, San Blas, the only sea-port which it possesses, being nearly abandoned. Foreign goods are introduced overland from San Luis or Mexico. There are here a mint and four printing-presses, all established since the revolution. The population of the capital is supposed to amount to seventy thousand souls. In this state is the magnificent lake of Chapala, from thirty-six to forty leagues in length, and varying in breadth from five to eight leagues.

Valladolid.

VALLADOLID.—Between the states of Guadalaxara and Mexico lies that of Mechoacan or Valladolid. It comprises the territory formerly belonging to the Tarascos, a powerful Indian nation, first allies, and afterwards rivals of the Aztecs, whom they are said to have followed in their emigration from the north. This state contains two cities, three towns, two hundred and fifty-six pueblos, three hundred and thirty-three haciendas, and one thousand three hundred and fifty-six ranchos, and is distributed into eighty-three parishes and twenty-one districts. The former riches of the state consisted almost entirely in its agricultural produce, the most ordinary manufactures being introduced from the neighbouring towns of the Baxio. But the agricultural interest is by no means in so flourishing a condition as it once was, nor are the mines remarkable either for their extent or their value. The whole western declivity of the Sierra Madre comprehended within the province of Michoacan is noted for its insalubrity; and the sea-coast, as might be expected, is likewise very unhealthy. The tierra caliente, at the foot of the Cordillera which is fertilised in part by the Rio Balsas, is rich in all the ordinary productions of the tropics; and even in the more elevated valleys, sugar was grown to a very considerable extent before the revolution. The best sugar lands are now about twelve leagues south of Pasquaro, the ancient capital of the Indians. At the foot of the mountain of Jorullo, there are plantations of cacao and indigo; and in several parts of the state the various productions of the table-land can be raised in abundance. Valladolid has been called the cradle of the revolution, from which it suffered severely. The population is estimated at about half a million.

Valladolid the capital of the state, is delightfully situated at the height of six thousand three hundred feet above the level of the sea. It consists chiefly of one long broad street, well paved, and kept in good order. The plaza is remarkable, as having broad piazzas on three of its sides, and the fine cathedral isolated from all other buildings, bounding it on the east. Here there is a crowded market where the venders display their goods, as is the general custom throughout the republic, beneath the shade of rude mat umbrellas. All the houses have flat roofs, with long water-spouts projecting most incommodiously over the streets. Besides the cathedral, which is crowded with a profusion of ornaments, there are several other churches, two nunneries, and four monasteries, for all which, besides an hospital and other public edifices, the inhabitants are indebted to the munificence of the bishops of the see. The population has been estimated at fifteen thousand.

La Puebla.

LA PUEBLA.—The state of La Puebla, which is situated to the east of that of Mexico, and stretches nearly across the continent, is divided into twenty-five districts, containing a population of above 700,000. The principal towns are Atlixco, which, in 1825, contained 31,657 inhabitants; Guauchinango 26,086; Ametopee, 25,151; La Puebla, 34,756; Tepeaca, 43,713; Tehuacan de las Granadas, 43,248; Hapa, 38,383; and Zacatlan 47,129. The territory of the state extends beyond the western ridge of the Sierra Madre, and down to the shores of the Pacific; consequently, it produces in abundance the fruits either of the tierra caliente, or those common to the rest of the table-land. There are, however, no mines which uniformly create a home market; and as the foreign trade is comparatively of but little importance, the agricultural interest is in a depressed condition. The native manufactures of wool and cotton have declined, as in other parts of Mexico. Some parts of the state, particularly the plains of Apan, are remarkable for their fertility. This state includes within its limits Tlascala and Cholula, the two cities which bade defiance to all the power of Montezuma. It contains also Popocateptl, the loftiest mountain in Mexico, and some remarkable remains of antiquity. The capital and largest city of this state is Puebla de los Angelos, the seat of the richest bishopric in the country, and that of the most extensive manufactures of cotton, earthenware, and wool. Glass and soap are also made, the latter to a considerable extent. The streets, like those of Mexico, are rectangular, spacious, airy, and paved with large stones in a highly ornamental manner. The houses are low, but commodious, and the apartments are mostly paved with porcelain and adorned with paintings in fresco. There are a great number of churches, convents, and above twenty colleges, with a magnificent cathedral, richly ornamented, and held in high veneration, in consequence of a tradition that it owes its origin to divine interference. La Puebla contains about 60,000 inhabitants.

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Oaxaca.

OAXACA.—Oaxaca is a very fine state, the southern boundary of which extends along the coast of the Pacific Ocean, from La Puebla to Guatemala. Agriculture is highly favoured by the fertility of the soil and the salubrity of the climate. The mineral riches which it contains, have not been fully explored, but there is no deficiency of mines. Cochineal is raised in abundance at Misteca; the cultivation of the insect being in the hands of Indians, who are said to be a race much superior to the other tribes upon the table-land. The women are called the Circassians of Mexico; and most of the families are affluent, above a million of dollars being annually employed in the purchase of cochineal. In ancient times this state was the seat of two independent kingdoms, viz. those of Misteca and Tzapoteca. Oaxaca the capital, called Antequera at the time of the conquest, is a flourishing place, although it suffered severely during the revolution. It contains above 20,000 inhabitants. This state has only one sea-port, Tehuantepec, and it is a bad one. The population is estimated at above half a million.

Vera Cruz

VERA CRUZ.—Vera Cruz is divided into four departments, viz. Vera Cruz, Jalapa, Orizava, and Acayucam, containing in 1825 a total registered population of 233,705 souls. It is a narrow strip of land stretching along the Gulf of Mexico from the state of San Luis Potosi to that of Tobasco, a distance of about four hundred miles, whilst its breadth on an average does not exceed fifty or sixty miles.

The department of Vera Cruz contains four cantons, Vera Cruz, Tampico, Papantla, and Misantla, having in all a population of 63,106 souls, distributed throughout the tierra caliente of the coast in fifty-three pueblos, rancherias, and congregaciones. The produce of these cantons consists in maize, frijoles, rice, cotton, sugar, woods of the most precious kinds, as mahogany, ebony, cedar; sarsaparilla, pepper, wax, indian rubber, and vanilla, which is very abundant in Misantla, where twenty thousand roots of it were planted in the year 1826.

The department of Jalapa is divided into two cantons, Jalapa and Jalacingo, containing forty-one pueblos and 53,061 inhabitants. Orizana comprises three cantons, Orizana, Cordova, and Cosamaluapam, with sixty-three pueblos, and 84,148 inhabitants. The population of Orizana and Cordova is employed chiefly in the cultivation of tobacco and of coffee. The towns contain several distilleries, and a number of bee-hives, which are important in a country where such quantities of wax are consumed. Acayucam is divided into three cantons, Acayucam, Tustla, and Nuimanguillo, and comprises twenty-three pueblos, having a population of 33,354 souls. The principal agricultural production is cotton, but the annual amount now raised has much declined. Almost all the trade of Mexico centres in Vera Cruz and its sea-ports.

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The city of Vera Cruz the capital of the state, is situated on the shores of the Gulf of Mexico in lat. 19.11.52 north, and long. 96.8.45 west. It is well and handsomely built of madrepore; and its red and white cupolas, towers, and battlements, have a splendid effect when viewed from the sea. Many of the houses are large, being built in the Moorish or old Spanish style, and generally enclosing a square court, with covered galleries. They have flat roofs, glass windows, and are well adapted to the climate. There is a tolerably good square, of which the government house forms one side, and the principal church another. There are other churches, as well as monasteries and nunneries. Opposite the town at the distance of about four hundred fathoms, is a small island, containing the strong castle of San Juan de Ulloa, which commands the town. The harbour lies between the town and the castle, and is exceedingly insecure. The anchorage is so bad, that vessels require to be moored to the castle by means of ropes attached to rings fixed in the walls; but even this is not found to be a sufficient safeguard against the fury of the northern winds, which sometimes blow here with tremendous violence. Vera Cruz is extremely unhealthy at all times; and during the warm season Europeans are exceedingly liable to become the victims of the vomito, or prevailing distemper. The city is surrounded by sand hills and ponds of stagnant water; there is neither garden nor mill near it; and the only water fit for use is that which falls from the clouds. For every article, except fish, many beautiful species of which are here caught, the markets are indifferent. The trade of Vera Cruz was at one period considerable, but it sensibly declined after Mexico threw off the yoke of Spain. Alvarado, a port about twelve leagues to the south-east, and which constituted the seat of martime commerce during the revolution, is built upon the left bank of a river of the same name, at the mouth of which there is a bar, rendering it inaccessible to vessels drawing more than ten or twelve feet of water. Large ships must consequently be loaded and unloaded by means of lighters. The trade of Mexico, however, has either reverted to its old channel, or is shared by Tampico, a port which has risen into importance within these few years. It is situated about sixty leagues north-north-west of Vera Cruz, in lat. 22° 15′ 30″ N. long. 97° 52′ W. being about an hundred and four leagues from Mexico. In 1825, the population of Vera Cruz amounted to about eight thousand.

Another town in this state is Jalapa, from which a well-known drug takes its name. Formerly it was the great mart of New Spain for European goods, as the unhealthiness of Vera Cruz compelled traders to transfer their merchandise at once to this city, where a great annual fair was held. It has now, however, little commerce of its own, and is only a sort of resting-place between Vera Cruz and Mexico. Jalapa is indebted to the peculiarity of its position for the extreme softness of its climate. The town stands upon a little platform, 4,335 feet above the level of the sea, and is protected from the north-west winds by a ridge of mountains. The height is exactly that at which there is a continual humidity in the atmosphere; but this only imparts a balmy feeling to the air, whilst it gives a delightful freshness to the face of nature. The town is neatly built, although the streets are irregular; and the houses without being remarkable for their size are of a superior order. Jalapa is the seat of government for the state of Vera Cruz, and here a large garrison is kept. The population is about 12,000.

San Luis Potosi.

San Luis Potosi.—To the north-west of Vera Cruz, lies the state of San Luis Potosi, under which name, as a Spanish intendency, were included Coahuila and Texas, New Leon, Tamanlipas and San Luis, now four sovereign states. San Luis, like the other members of the federal republic, is divided into several districts, which, in 1825, contained a population of 250,000 souls. Most of the haciendas are only vast sheep walks, although many of them might be rendered a source of great wealth. In this state, there are a number of rich mines, particularly those of Catorce, where a metalliferous ridge of mountains extends for many miles. The state congress is composed of fourteen deputies elected in the proportion of one for every twenty-thousand souls. In ecclesiastical matters, San Luis is dependent upon the bishoprics of Guadalaxara and Valladolid, between which the spiritual jurisdiction is divided. With the exception of the capital which bears the same name, it possesses no large town. San Luis, including the suburbs, contains between fifty and sixty thousand inhabitants. It is well built, and contains a number of churches, monasteries, and public buildings. The exterior architecture of the sacred edifices is generally heavy, being overloaded with carved ornaments, and ill-executed statues of saints; yet at a short distance, they give a magnificent appearance to the town. The palacio, now the house of the provincial congress, forms one side of the Plaza de los Armas, which has an excellent fountain of water in the centre. The parroquia, or cathedral, occupies a portion of the opposite side, and on its right are the soldiers' quarters. The two other sides are filled with shops and dwelling houses. The former are good and well stocked, those for the sale of liquors being by far the most numerous. To excessive indulgence in the use of pulque and other stimulants, must be attributed the frequent brawls and assassinations which take place in San Luis. San Luis derives great advantage from its situation, as the natural dépôt for the trade of Tampico with the northern and western states. Zacatecas, Durango, and other states, receive through this channel a large proportion of their foreign imports; and since the building of the new town of Tamanlipas, which, from being on a more elevated spot than the old town (pueblo viejo) of Tampico, is less subject to the vomito, there is every appearance of a rapid increase in this branch of commercial intercourse.

Zacatecas.

Zacatecas.—To the west, and north-west of San Luis Potosi, is situated Zacatecas, a state divided into eleven districts, viz. Zacatecas, Aguas Calientes, Sombrerete, Tlaltenango, Villanueva, Fresnillo, Jerez, Mazapil, Nieves, Pinos, and Juchilipa, which, in 1825, contained a registered population of 272,901 souls. There are in this state one hundred and twenty haciendas, with six hundred and sixteen ranchos; but most of the latter consist merely of three or four wretched hovels. Zacatecas is both a mining and an agricultural state. Manufactures there are none, excepting in the capital, where there are a few cotton spinners, as also at Aguas Calientes. The revenue of this state exceeds the expenditure, tobacco being the most productive branch of industry. A little maguey brandy is distilled at Pinos; but every thing else requisite for the consumption of the inhabitants is imported from other states. As a mining district, Zacatecas differs materially from Guanajuato; for instead of one great principal vein, it contains three lodes, nearly equal in importance, viz., La Quebradilla, San Bernabe or Malanoche, and Veta Grande, with a number of inferior vetas and vetillas, which may be considered as ramifications of the principal lodes. The principal mines of Zacatecas are in the hands of companies. Aguas Calientes, south of the capital, is a highly cultivated district, producing nearly one-fourth of the maize, and one-third of the frijole and chile grown in the state; but to the north and east of this district the country is divided into vast breeding farms, where the population is thinly scattered over an immense tract of country. The constitution of Zacatecas was completed as early as January 1825. The legislature consists of one chamber.

Zacatecas the capital is situated at the foot of an abrupt and picturesque porphyritic mountain, upon the rugged summit of which is perched a neat church and a small fortress. From the inequalities of the ground on which it stands, the streets are short and crooked. Besides a very noble cathe-

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dral, it contains a number of churches and convents. Amongst the public buildings worthy of notice, may be mentioned the mint, the best in Mexico, and "la casa del Ayuntamiento," a magnificent edifice, where all the public offices are established, and where the congress of the state assembles. This town contains about twenty-two thousand inhabitants; and Veto Grande, a village in its immediate vicinity, contains six thousand.

Yucatan.

YUCATAN, or MERIDA, the southern extremity of Mexico, is a peninsula which projects into the ocean above four hundred miles, and may be said to separate the Gulf of Mexico from the Carribbean Sea. It is a vast plain of alluvial formation, intersected by a mountain ridge which does not exceed four thousand feet in height, comprising an area of three thousand eight hundred and twenty-three square leagues, and divided into fifteen departments, which, in 1825, contained a registered population of 496,990 souls. Upon some parts of this extensive territory, maize, frijoles, rice, cotton, pepper, tobacco, and the sugar cane are produced, besides dye-wood, hides, and other articles. In the central parts, the want of water is a very serious drawback to agriculture; the rainy season is very uncertain, and in many parts not even a stream is known to exist, so that in unfavourable years, the inhabitants are compelled to have recourse for subsistence, to the roots which the woods supply. There are no mines, and the extensive trade which was once carried on with the Havanna was cut short by the war, nor has it been as yet restored. The capital of Yucatan is Merida, situated on an arid plain forty miles from the coast. It enjoys little trade, and contains only about ten thousand inhabitants. Campeche is the principal commercial town; and here the log-wood, which goes by the same name, attains its greatest perfection. There was imported into Great Britain from Mexico in 1831, four thousand eight hundred and eighty-five tons of this wood, the greatest part of which was shipped at the port of Campeache. The town contains about eight thousand inhabitants. The receipts of Yucatan in 1826, amounted to 213,127 dollars, whilst the expenditure for the same year was 207,199, thus leaving a small balance in favour of the state.

Tabasco.

TABASCO.—Immediately adjoining Yucatan, is the state of Tabasco, which is divided into three departments and nine districts, containing in all forty-eight pueblos, sixty-three churches, five hundred and forty-three haciendas, and fifty-four thousand eight hundred and sixty-two inhabitants. A large proportion of the territory of this state is laid under water during the rainy season, and intercourse between the villages must be carried on by canoes. This circumstance is favourable to the growth of cacao, supposed to be an indigenous plant, and now cultivated to a considerable extent. Coffee is likewise grown, and the pepper which goes by the name of the state, is found in great abundance on the banks of rivers. Indigo and vanilla grow wild, though little attention is paid to their cultivation. The revenue of this state does not exceed fifty-thousand dollars, and the expenditure was in 1827, nearly the same.

Las Chiapas.

LAS CHIAPAS. Between Tabasco and part of Guatemala is situated the state of Las Chiapas, formerly a part of central America, but now united to Mexico. The soil is fertile, and capable of yielding in profusion tropical fruits and grain. The cacao, although very fine, is not cultivated to any extent. The Chiapa of the Spaniards, called also Ciudad Real, though ranking as the capital, is now only a small place, containing four thousand inhabitants. A town of the same name, occupied by Indians, is larger, and carries on the chief trade, which, however, is inconsiderable.

Durango.

DURANGO.—The state of Durango, or New Biscay, has a great extent of surface, about sixteen thousand square leagues, yet in 1825 the population was estimated at only 175,000. It is divided into ten districts, viz. Durango, Nombre de Dios, San Juan del Rio, Cinco Señores de Nazas, Cuencame, El Oro, Indee, Papasquiaro, Tamascula, and Guarisamey. Its riches depend entirely upon its mines and agricultural produce; which last is so considerable, that the lands already brought under cultivation are supposed to be sufficient for the support of a population about five times as large as that which the state now contains. The farms are upon a large scale, and are chiefly devoted to breeding horned cattle, mules, and sheep. Some haciendas, however, are entirely laid out in corn lands; but although indigo and coffee are found wild in some parts, and sugar might be raised to almost any extent, little attention has hitherto been paid to them. Fruits and vegetables of all kinds abound, particularly peaches and potatoes. Maize, flour, oxen, cows, sheep, mules, and horses, are astonishingly cheap. With the exception of a glass manufactory, a tannery, and the fabrica de tabacos, Durango is destitute of manufactures; but the richness of its mineral deposits compensates for any deficiency in this respect. There are a great number of mines, none of which, with one or two exceptions, have been worked to any extent. The chief mining districts are consequently virgin ground; and there are few in which the old shafts might not again be brought into activity at a trifling expense. Besides the mines of gold and silver, which are situated on either side of the Sierra Madre, there are some of iron and lead, both of which metals might be obtained in abundance. In the vicinity of the capital, materials for building abound, stone and lime being found at a very little distance from the gates; and the flint used in the manufacture of glass is readily obtained. The constitution of Durango is framed in a liberal spirit. The congress consists of two chambers, containing eleven deputies, and seven senators.

Durango, or, as it is now called, Victoria, the capital of the state, is situated sixty-five leagues to the north-west of Zacatecas, in the midst of a vast plain. Both the city of Victoria, and most of the other towns of Durango, as Tamasula, Sianori, Mapimi, San Dimas, Canelas, Cuencame, and others, take their origin from the mines. Before the discovery of those of Guaresamey, Victoria was a mere village, and as late as 1783, it contained only eight thousand inhabitants. In 1825, the population was estimated at twenty-two thousand. The principal streets, the plaza mayor, the theatre, and most of the public edifices, were built by Zambrano, a wealthy proprietor, who is supposed to have drawn from his mines at San Dimas and Guarisamey, upwards of thirty millions of dollars. The towns of Villa del Nombre de Dios, San Juan del Rio, and Cinco Señores de Nazas, are almost the only considerable places in the state unconnected with the mines. The great mineral wealth of this state holds out the most encouraging prospect of ample remuneration to those who engage in mining speculations; and there can be little doubt, that ere long, the advantages which Durango possesses, will be duly appreciated by foreign or native associations of capitalists.

Chihuahua

CHIHUAHUA.—The state immediately adjoining Durango to the north is that of Chihuahua. The inhabitants, who, by the last census were estimated at 112,694 souls, are thinly scattered over a vast tract of country, occupied by great breeding estates, abounding in mules and horned cattle. But agriculture is comparatively neglected; the mines, in which this state is very rich, holding out a better prospect of ample reward for industry. A minute description of the mining districts would greatly exceed our limits; it is only necessary to mention those of Jesus Maria, San Jose del Parral, on the eastern ridge of the Sierra Madre, the famous mines of Batopilas, on the western declivity, El Carmen, Dolores, Candelaria, Buen Suceso, San Antonio, Pastraña, and Arbitrios. Some of them are amazingly rich, and capital to employ labourers is alone required to raise this state to wealth and importance. The revenue, in 1825, was 69,369

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dollars, and its expenses, including the contingent, 63,422 dollars. For an account of CHIHUAHUA, the capital, see the article under that head.

Sonora and Sinaloa

SONORA and SINALOA.—To the west of Chihuahua extends the vast state of Sonora and Sinaloa, occupying the whole space between twenty-two and a half and thirty-three and a half degrees of north latitude, and forming the eastern coast of the Gulf of California as far as the Cerro de Santa Clava, where commence the Indian lands south of the rivers Gila and Colorado. It contains an area of above nineteen thousand square leagues. To this vast extent of surface, however, the population bears no proportion. It was estimated by Humboldt at 121,400 souls; but it probably exceeds that number, as various Indian tribes inhabiting this territory were not likely to submit to exact registration. In many parts the soil is exceedingly fertile, and the productions of both the temperate and torrid zones may be raised within this territory. It is likewise rich in mineral treasures; many of the mines being of great value, whilst their depth is inconsiderable. The southern part of Sonora, properly called Sinaloa, is separated from Jalisco by the river Canas or Bayona, twenty-five leagues from which is Rosario, a handsomely built town, containing six thousand inhabitants. It is a place of great commercial importance, being the dépôt for the port of Mazatlan; and a very considerable trade is likewise carried on with the states of Durango and Jalisco. In its vicinity is a celebrated mine of the same name, one of the oldest and best in the republic, and still wrought to some profit. Twenty-five leagues from Rosario is the port of Mazatlan, which, though by no means a safe one, is rising into importance. The town is miserable, consisting mostly of about a hundred huts composed of mats, hides, and palm leaves, and destitute of any defence, excepting the dangerous shoals and rocky islands which encumber the entrance to the small bay upon which it stands. Guaymas, the best port in the republic, is situated in lat. 27. 40. N., about the middle of the Gulf of California. The harbour is excellent, well sheltered, and capable of containing two hundred vessels. The town contains above three thousand inhabitants, amongst whom are many merchants. The imports consist of Chinese, East Indian, and European manufactures, and the exports of wheat, flour, beef, hides, furs, copper, silver, and gold. The heat in summer is great, yet the town is healthy, neither the vomito nor the cholera being known. In 1825 there was a custom-house established at both of these ports, and the latest returns shew an increase of revenue from this source. The chief dépôt of commerce for the whole of Upper Sonora and the port of Guaymas is Petic, which is situated in a plain near the confluence of the rivers Dolores and Sonora, lat. 29. 17. N. long. 111. 3. W. The town is very irregularly built, but contains many excellent houses, and about eight thousand inhabitants. The neighbourhood is fertile and well cultivated, affording abundance of the necessaries, and many of the luxuries of life. The vine thrives well, and from it a good wine is made, and brandy also distilled. The wheat of Sonora is considered as the best grown in the republic. Vegetables of every description are plentiful and cheap, and fish are abundant. Fourteen leagues to the westward of Petic is the town of San Miguel de Horcasitas, upon the river Dolores. To the north of this town, appear the first ramifications of the Sierra Madre, abounding in mines of silver, gold, and copper. From San Miguel to Uves, on the southern bank of the river Sonora, the distance is twelve leagues. It is a handsomely built place; the streets are wide and regular, and there is a large square, in which are a church and convent. To the north of it, two ridges from the great Cordillera intersect the country, running parallel to the Pacific, and separated by the Dolores, Sonora, Oposura, and Barispe, rivers in all of which gold has been found.

To the north-west of Uves, and situated on a table-land, is the town of Babiacora, which contains three thousand inhabitants, more than three-fourths of whom are Indians. The vale of Sonora extends from this town about twelve leagues in a northerly direction, and is considered as one of the most productive districts in the state. It contains the towns of Conche and Sonora, besides a number of haciendas and farms, and a considerable population. In the neighbourhood of Babiacora are numerous mines, both of gold and silver. Eighteen leagues to the eastward is the town of Oposura, situated upon a river of the same name, and containing above four thousand inhabitants. The vale of Oposura is about twenty-six leagues in length, and varies from one to four leagues in breadth. The population consists partly of whites, who have preserved the blood of their Biscayan ancestors in all its purity; and partly of Indians of the Opata tribe, who in Upper Sonora compose nearly two-thirds of the inhabitants. The whole of this country is rich in every variety of agricultural produce. North of Arispe and the Presidio of Fonteras (lat. 31.), is the country of the Apaches, an independent Indian tribe. This people are brave, and dexterous in the use of weapons, but averse to the forms of civilised life. The road from Arispe to the Villa del Fuerte, the capital of Sinaloa, runs nearly due south for one hundred and twenty leagues. The principal towns on the way are Onabas and Los Alamos, a celebrated mining district. To the north and north-west of the latter place, between the rivers Yaqui and Mayo, there are vast plains, inhabited by numerous tribes of Indians, who have become reconciled to the restraints of civilized life, and possess numerous towns, where they cultivate the arts of peace. El Fuerte, which was originally a military station, is now the residence of the governor of the state; the congress, which consists of eleven members, and the supreme tribunal of justice, also hold their sessions in this place. The tierra caliente of Sinaloa extends from Alamos to the confines of Guadalaxara. It is one vast unproductive sandy plain. Culican, the most ancient and most populous town in Sinaloa, is situated on a river of the same name, eighty leagues south of El Fuerte, and contains a population of eleven thousand souls. There are numerous other towns and mining districts in this state, which possesses extraordinary natural advantages, and may be considered as one of the most important territories of the republic.

Tamanlipas and New Leon

TAMANLIPAS and NEW LEON.—Along the shores of the Gulf of Mexico, and to the north of Vera Cruz, extends the state of Tamanlipas. A considerable part of this state is traversed by the great river Bravo del Norte, at the mouth of which is the harbour called El Brazo de Santiago. It is situated on the river Panuco, which separates Tamanlipas from Vera Cruz, about three miles to the northward of the old town of Tampico, or as it is called, Pueblo Viejo. There are indeed three towns which bear the name of Tampico in this quarter. Pueblo Nuevo de las Tamanlipas is of recent erection, and built on a neat model. It is rapidly increasing. Altamira is a little town situated on the road to San Luis Potosi. A considerable portion of this state, being low in situation, is warm, and capable of producing tropical fruits and vegetables; whilst on the more elevated parts are found the usual productions of the temperate zone. Tamanlipas possesses various mines, not only of the precious metals, but of copper, lead, and tin; and there are several crystalising salt lakes in the territory.

To the westward of Tamanlipas lies the state of New Leon. The soil is fertile, and the climate, although warm, is very fine, producing abundance of corn and fruits. It abounds in excellent and extensive pastures, on which are bred numbers of cattle. Monterey, the capital, occupies part of a large plain, surrounded by mountains (part of the Sierra Madre), in lat. 26. N. Fruits abound during the whole year, and provisions of all kinds are plentiful and cheap. It contains fifteen thousand inhabitants. Linares is a pretty large town, situated some leagues to the east of Monterey, on an

Political divisions.

elevated plain between two rivers. It contains some well built houses, and about six thousand inhabitants.

Cohahuila.

COHAHUILA.—Adjoining to New Leon and Tamanlipas is Cohahuila which is generally elevated, and being well sheltered from the north-west winds, possesses a healthy climate. A considerable mountain chain stretches across the state in a north-westerly direction, and its surface is most luxuriantly irrigated by the numberless springs and streams which, bursting from these ridges, become tributaries to the great river Bravo del Norte. Its pastures are clothed with rich natural grasses, and are admirably calculated for breeding, rearing, and fattening cattle; whilst its forests furnish abundance of wood, which is well calculated for every kind of construction. There are mines of saltpetre, copperas, alum, lead, tin, and copper, besides some silver in Santa Rosa, and gold in Sacramento. These mineral treasures, for want of population and of capital, have been rather ascertained than explored. The inhabitants are almost wholly of the white race, or with such slight mixture of the Indian blood, as to make no distinction in colour worthy of notice. The native tribes within the province have been extinguished; but on the borders towards the north and west are several warlike tribes of Indians. In these parts also there are droves of wild cattle and horses, and herds of buffalos. Monclova is the capital of the state, but Leona Vicario, formerly Saltillo, is the largest town, containing about twelve thousand inhabitants. It is situated upon the side of a hill, branching off from the Sierra Madre, which in this quarter presents nothing but barren rocks, whilst the intervening valleys or plains are all nearly destitute of vegetation. In 1811, Cohahuila contained between seventy and eighty thousand inhabitants, and it does not appear that their numbers have materially increased since that time. They are chiefly occupied in agriculture, and produce excellent wheat and barley, and great variety of fruits. The vines cultivated here make wine of very excellent flavour, and considerable strength.

Texas.

TEXAS.—Texas is a north-eastern province of Mexico, situated between 27. and 35. of north latitude, and 93. 15. and 102. 30. of longitude west from Greenwich. It is bounded on the north by Red River, which divides it from Arkansas, Ozrack district, and New Mexico; on the south by the gulf of Mexico, and the Rio de las Nueces, which divides it from Cohahuila and Tamanlipas; on the east by the eastern branch of the river Sabino, and the state of Louisiana; and on the west by Cohahuila and the territory of New Mexico. In medium length from north to south it extends five hundred and forty miles; its average breadth from east to west is four hundred and sixty miles, and it contains an area of one hundred and fifty thousand square miles. This extensive territory, which is described as forming a vast inclined plain, is one of great natural beauty and fertility. It is intersected by a number of large rivers, amongst which may be enumerated the Brazos, which has a great many branches, and a south-easterly course of six hundred miles; the Colorado, also with numerous branches, and a south-easterly course of four hundred miles; the Trinity, the Guadalupe, the Sabine, the San Antonio, the Medina, Nueces, Naches, and Rio del Norte, all having long courses and numerous branches. There are several secondary streams which, although they have short courses, are of very great importance in an agricultural point of view.

The country is very open, being principally composed of extensive prairies, but it is more minutely divided into plain, undulating, and mountainous. The plain country, which may be termed a dead level, with only here and there a gentle slope, is thirty miles broad at the Sabine; gradually extends its breadth to about one hundred miles on the Colorado, the centre of the level land; afterwards it shrinks to narrow limits; and on the Nueces it declines to a point. This vast tract of territory presents considerable variety of soil and natural productions, being in some parts a low, woody, cane brake country, and in others, sunken prairie land, having a sterile and cheerless aspect; but this gradually disappears, and large, rich, and magnificent prairies, intersected with variegated clumps of timber, extend on either side of the Colorado and Brazos. By far the largest portion of Texas consists of undulating country; it has been described as "lying in the form of a triangle with the centre of its base line on the Sabine in lat. 32°., and its vertical point resting on the Colorado, long. 20° 30′."[1] It is remarkably salubrious, abounds in streams and springs, timber of various kinds, as well as fine pasturage, where cattle may be raised to an unlimited extent, beautiful and varied scenery, and is nearly free from noxious insects. The soil both of the prairies and the undulating country is generally a deep dark mould; but the streams are usually bordered by tracts of alluvial land which yield a variety of timber. The mountain range of Texas consists of spurs or branches of the great Sierra Madre, which, in point of elevation, are only of the third or fourth order. They are in many parts thickly covered with forests, interspersed with a great variety of shrubbery. Extensive valleys of alluvial soil are found throughout this range, more particularly on the water courses. The scenery of this country is at once grand and beautiful, and much of the land is susceptible of cultivation. With regard to the extent of arable soil in Texas, Mr. Edward observes; "East of the Trinidad river there will be found one-third of the whole fit for the plough. Between the Trinidad and the Colorado rivers one-half of the lands are tillable. West of the Colorado one-fourth of the surface can be laboured."

Political divisions.

The natural productions of Texas comprehend most of those which we have described as belonging to Mexico in general, and do not therefore require to be specified. There is abundance of timber of various kinds, fruit trees and shrubs, amongst which may be mentioned the vine, minerals and metals useful in the arts, wild and domesticated animals, and fish and fowls of every description. The alluvion upon the water courses is admirably adapted for the cultivation of cotton and sugar; whilst corn, wheat, and other grains can be raised almost everywhere, and tobacco and indigo in many parts. There is unlimited pasture for cattle during the whole year. No country is so admirably adapted for sheep, and there is a plentiful supply of mast for hogs. Indeed the resources of this beautiful country, which remained almost unknown to the Spaniards, are very great, and industry and enterprise are only necessary to turn to account the natural advantages which it possesses.

The southern and eastern portions of the country, which are at present of the most importance, are divided into three political jurisdictions, namely Nacogdoches, Brazos, and San Antonio de Bexar. The department of Nacogdoches is bounded on the north by Red River, on the south by the Gulf of Mexico, on the east by the river Sabine, and on the west by the department of Brazos. The capital, which bears the name of the district is situated in a romantic dell surrounded by wooded bluffs, sixty miles west of the river Sabine, in lat. 31. 36., north, and long. 94. 36. It is a flourishing town containing about one thousand resident inhabitants. San Augustin is situated on Ayish Bayou, an eastern branch of the river Naches, fifteen miles west of the Sabine, and forty-five miles east of Nacogdoches. From being placed in the centre of one of the richest landed districts in the state, its improvement has been very rapid, indeed more so than that of any other town in Texas. Anahuac, although at present only the third town in the department in point of size, is, from its peculiar advantages, destined ere long to be the first. It is situated on a beautiful high level prairie bluff, to the south-

[1] Edwards' *History of Texas*, Cincinnati, 1836.

Political divisions.

east of Galveston bay, in a comparatively healthy spot opposite the mouths of the Trinidad river, and is thus likely to become the grand dépôt of maritime commerce.

The population of Texas has been estimated at seventy thousand. But there are, besides, numerous Indian tribes, either located in particular districts, or who lead a wandering life, and make frequent descents upon the settled parts of the country. Of the numbers actually within the limits of the state no estimate can be formed.

New Mexico.

New Mexico.—Texas is bounded on the western side by the arid mountains of San Saba, and by elevated plains, which serve only to afford pasture to the buffaloes and other wild animals. To the westward of this desert tract extends the state of New Mexico, a long and comparatively narrow strip of country, through which the Rio Bravo del Norte takes its course to the ocean. Though the latitude of New Mexico is not higher than that of Syria and Persia, the climate is very cold. The chief productions are the grains of Europe; and there is abundance of pasture for animals. The banks of the Rio Bravo are well wooded and highly picturesque. On either side are fine plains, which are rendered fruitful by artificial irrigation. The capital of New Mexico is Santa Fé, situated to the east of the great river, in lat. 36. 12. N., and long. 104. 52. 45. W. It is the centre of a considerable overland trade between the northern part of Mexico and the western parts of the United States; and from this point proceeds the great trading road to St. Luis, in the Missouri territory. Albuquerque, to the west of the Sierra Obscura, has a population of six thousand; and Taos, to the north, has about nine thousand. The Paseo del Norte is a place at which travellers must provide themselves with food to subsist on during their journey of sixty leagues over the desert which separates it from Santa Fé. The fields there are well cultivated with maize and wheat, and the vineyards produce excellent sweet wines. The gardens are well stocked with figs, peaches, apples, pears, and the other fruits of Europe. Artificial irrigation is here conducted on very simple but very good principles, and the effect is visible in all their crops. The population of New Mexico has been estimated at fifty thousand.

California.

California.—Referring to the articles which appear under this head, we may mention, that, since they were written, some additional information respecting this interesting portion of Mexico has been obtained, chiefly through Dr. Coulter.[1] Upper California extends from the coast of the Pacific to the Rio Colorado, and from the boundary with Lower California, a few leagues south of San Diego, to the parallel of 42½ degrees north latitude. But the course of the Rio Colorado is entirely within the Rocky Mountains, which are separated from the inhabited, and indeed habitable, portion of California, by a great sand plain, destitute of water. "The plain is about one hundred miles in breadth, at its southern extremity, and about two hundred at the northern; about seven hundred miles in length, gradually ascending toward the north, and similar in every respect to that on the eastern side of the Rocky Mountains. Our view is thus confined then to a narrow tract of country of very remarkable features, the general run of its mountain ridges, continuous with the chain of Lower California, being nearly parallel with the coast, and almost all the minor streams running north-westerly. Of the great rivers falling into the bay of San Francisco, through the Boca de Carquinas, the Sacramento only has a southern course. The Jesu Maria and the San Joaquin run westerly or north-westerly, as do all the others collected in the Tule lakes, before entering the bay." These lakes "are now known not to exceed a hundred miles in total length, being fordable in the dry season in several places; and notwithstanding their many tributaries from the eastward, they discharge during a considerable portion of the year, very little, if any, water into San Francisco. It is only immediately after the rainy season, which is usually ended by February, and during the thaw of the snow on the high range of hills between the lakes and great sand plain, that there is any considerable discharge of water from them in this direction. Such, at least, is the account given by the American hunters. Limited, as we have supposed, to the eastward by the sand plain, the general form of the country is somewhat triangular, the ridge of mountains from Lower California dividing into several others, which slightly diverge as they advance northward. The great snowy peaks of San Bernardino, east of San Gabriel, being the point from which the two principal ranges start, the one the great snowy chain, separates the sand plain from the Tule lakes, and the other separates the Tule lakes from the sea board, not running further north than San Francisco." The only settled portion of Upper California is that along the coast, the missions being nearly all within one day's journey of it. The valley is of considerable size, and many parts are exceedingly fertile, producing the finest wheat and the most luxuriant vines. But the great article of produce of Upper California is black cattle, which have increased with astonishing rapidity. Only seventy years have elapsed since twenty-three head were first introduced; and in 1827 the missions possessed 210,000 branded, and not less than 100,000 unbranded cattle. It is found necessary to slaughter sixty thousand annually, to keep the stock at the present standard, until more of the country be settled to the eastward. Sheep have increased with nearly equal rapidity, but are as yet of little interest to the trade of California, their price having been kept enormously high by the priests. "It is sufficiently strange," says Dr. Coulter, "that where the fattest bullock is worth only eight dollars, and can rarely be sold at all, and where young cows with calf can be bought in droves at about two dollars, and frequently less, a sheep cannot be bought for less than three dollars." The white inhabitants have increased rapidly, and are now estimated at about six thousand, whilst the aboriginal population has considerably diminished in number.

The two Californias are to be considered as forming one great chain of mountains, with several long but usually narrow valleys dividing it into ridges nearly parallel with the coast, and as a whole separated by the gulf of Cortez and the great sand-plain, from Sonora and the Rocky Mountains; with the latter, however, the California chain appears ultimately to unite north of the parallel of 42°, about the great summit level, dividing the waters of the Columbia from those falling into the bay of San Francisco. The neighbourhood of this bay is the only part of the country likely ever to become of much interest to Europeans. It is highly fertile, well wooded, watered, and perfectly healthy. Lower California is pretty rich in minerals. Dr. Coulter mentions having seen very rich argentiferous lead ores from the southern extremity of it; and gold is also found in several places.

[1] Coulter's *Notes on Upper California. Journal of the Royal Geographical Society of London*, vol. v. part i. 1835.

END OF VOLUME FOURTEENTH.

Printed by Thomas Allan & Co., Neill & Co.,
and Balfour & Jack,
and Stereotyped by Thomas Allan & Co.

Beluga Arctica.

Oxypterus Rhinoceros.

Delphinapterus Peronii.

Geo. Aikman, Sculp.t

Poli
divis

New
ico.

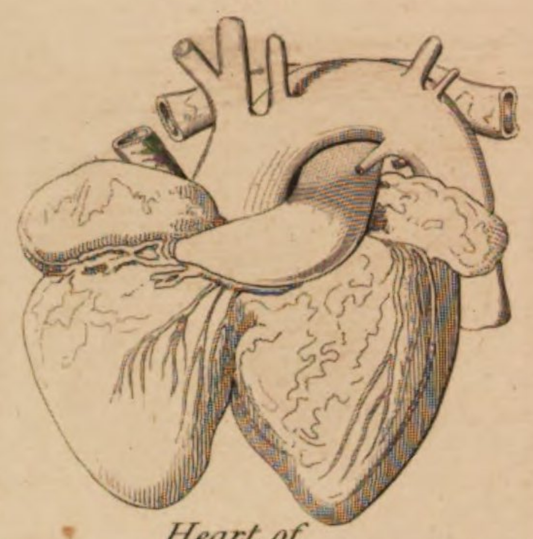
Calif

MAMMALIA.

1.

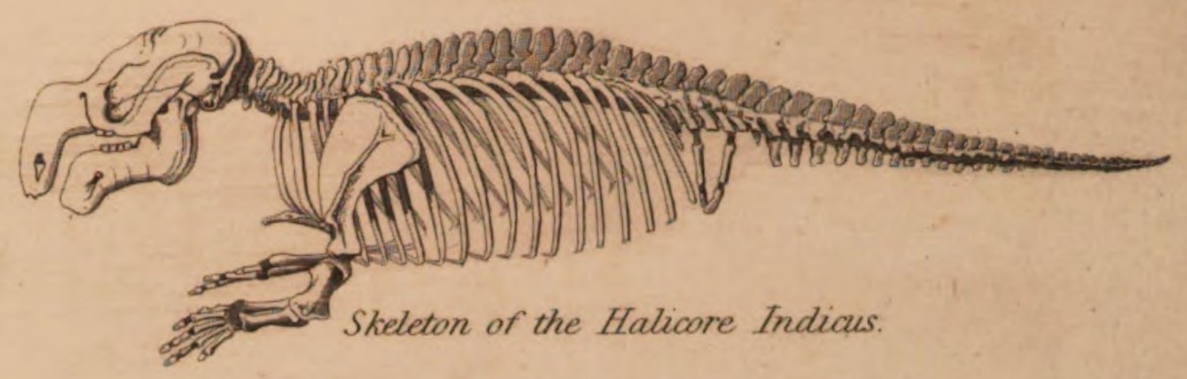
Manatus Americanus.

2.



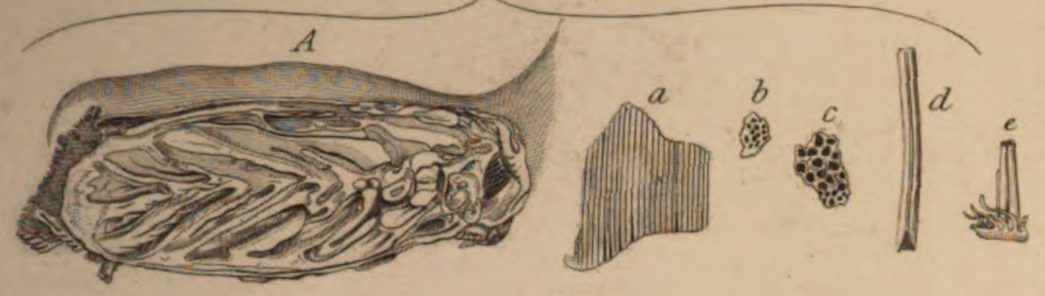
Heart of Halicore Indicus and Stellerus.

3.



Skeleton of the Halicore Indicus.

4.



Tooth of the Stellerus.

5.

Teeth of the Inia.

6.

Genus Soosoo.

7.

Genus Delphinorhynchus.

8.

Genus Delphinus.

9.

Genus Phocæna.

10.

Genus Globicephalus.

11.

Inia Boliviensis.

12.

Delphinus Delphis.

13.

Soosoo Gangeticus.

14.

Delphinorhynchus Bredanensis.

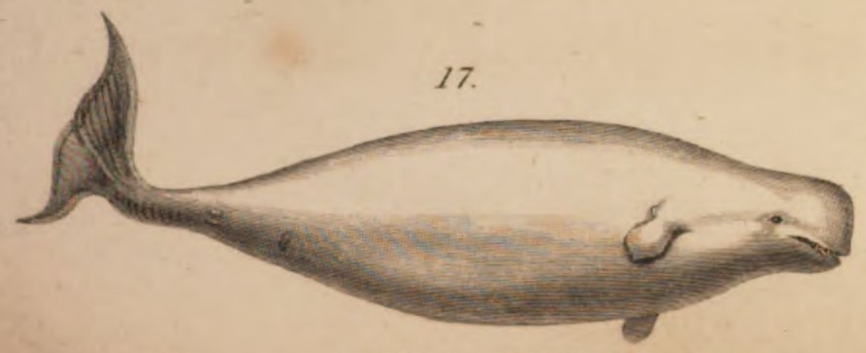
15

Phocæna Communis.

16.

Globicephalus Deductor.

17.



Beluga Arctica.

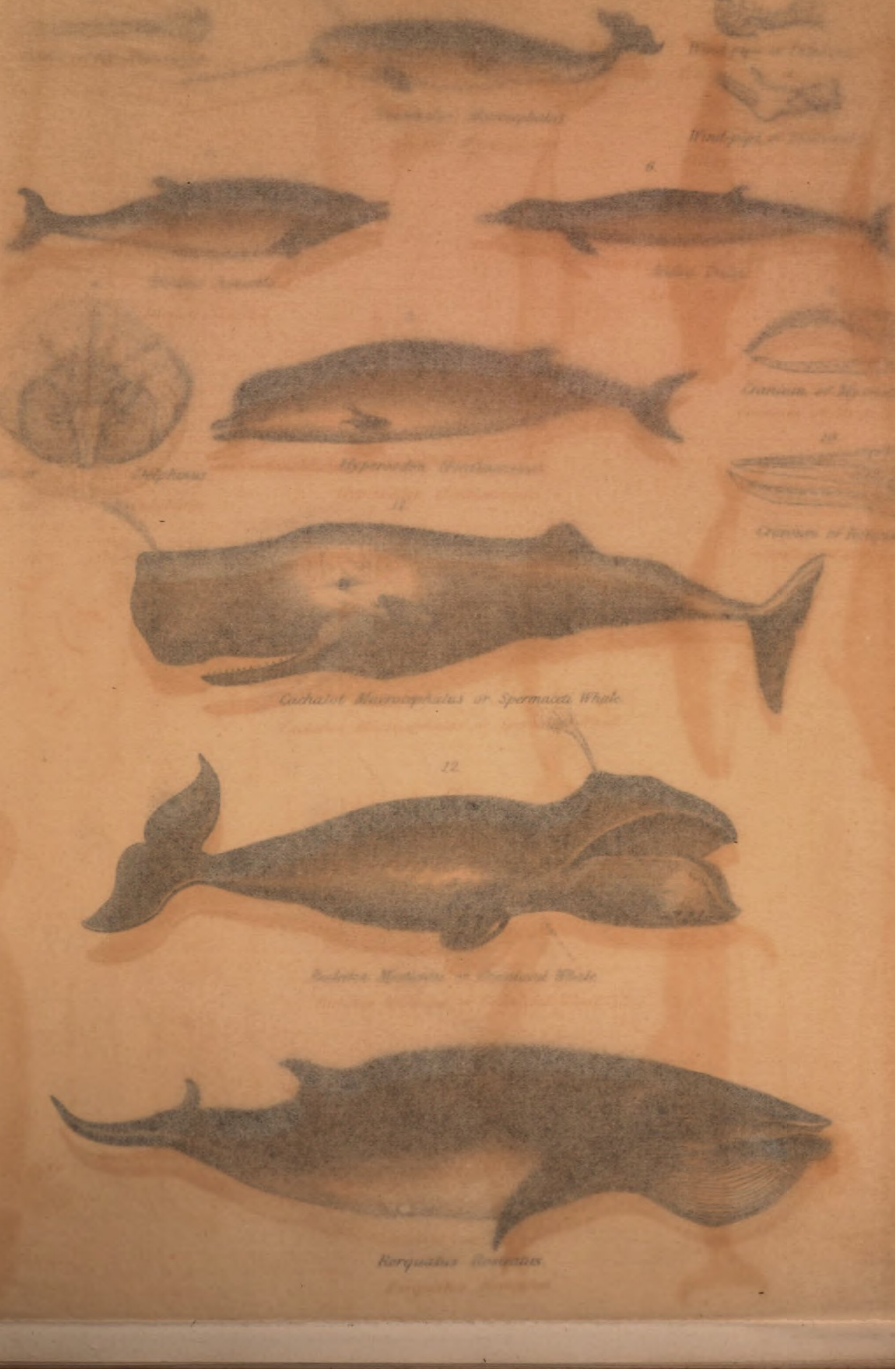
18.

Oxypterus Rhinoceros.

19.

Delphinapterus Peronii.

Geo. Aikman, Sculp.t



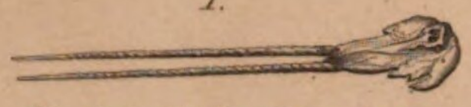
Cachalot Macrocephalus or Spermaceti Whale

12

Balaena Mysticetus or Greenland Whale

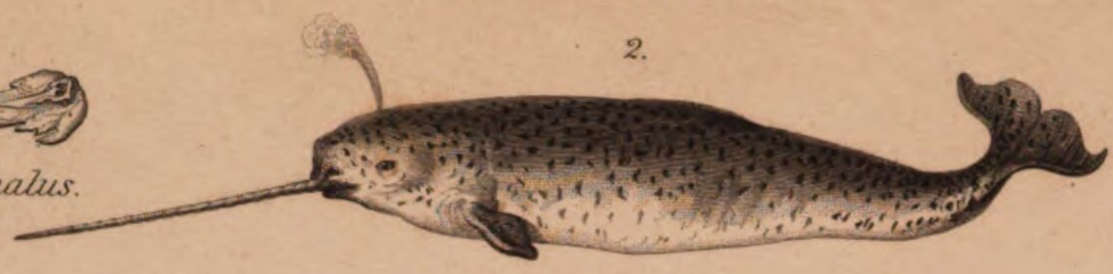
Balaena Boops

1.



Tusks of the Narwhalus.

2.



Narwhalus Microcephalus.

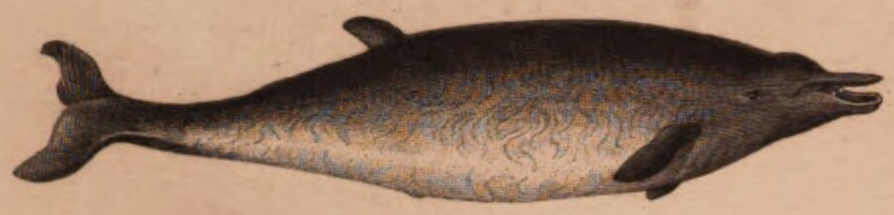
3.

Wind-pipe of Delphinus.

4.

Wind-pipe of Narwhalus.

5.

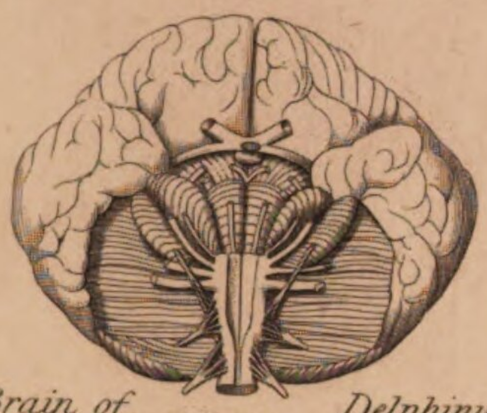


Diodon Sowerbii.

6.

Aodon Dalei.

7.

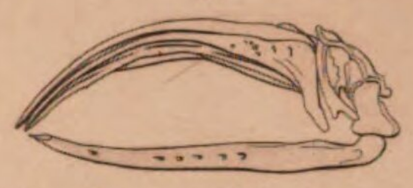


Brain of Delphinus.

8.

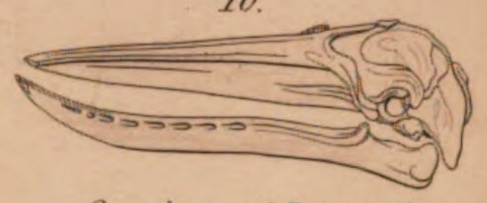
Hyperoodon Honfleuriensis.

9.



Cranium of Mysticetus.

10.

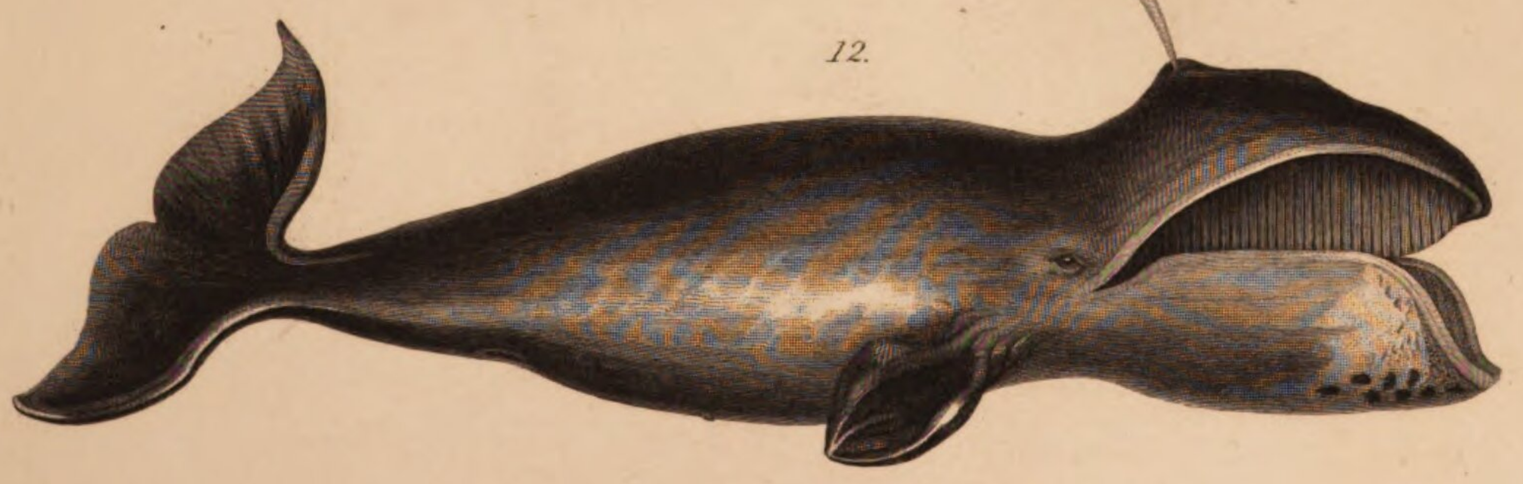


Cranium of Rorqualus.

11.

Cachalot Macrocephalus or Spermaceti Whale.

12.



Balœna Mysticetus or Greenland Whale.

13.

Rorqualus Rostratus.

Geo. Aikman, Sculpt.

Fig 3.

F

Sculpt

Fig. 1.

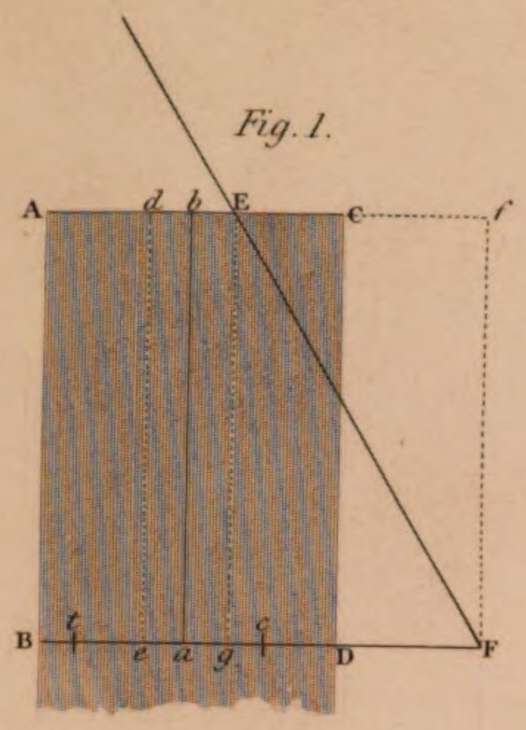


Fig. 2.

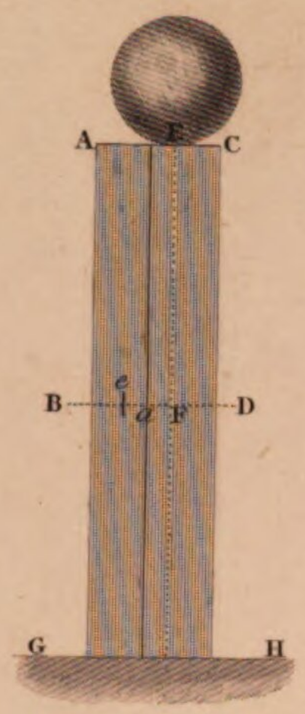


Fig. 4.

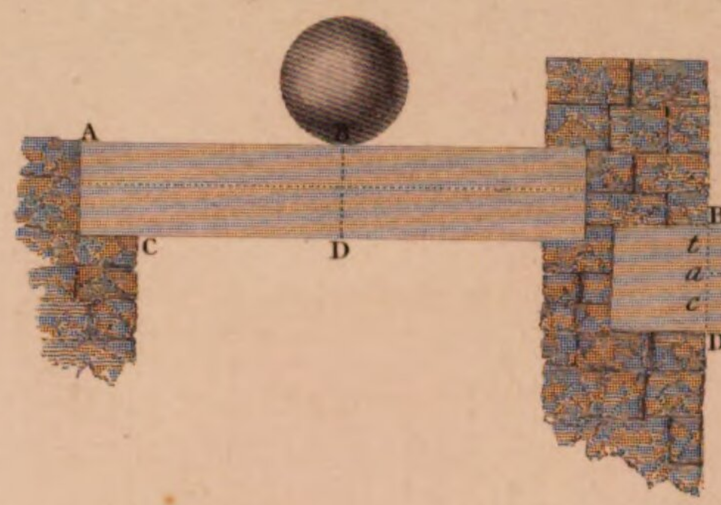


Fig. 3.

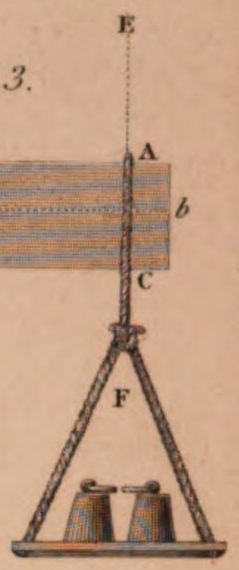


Fig. 5.

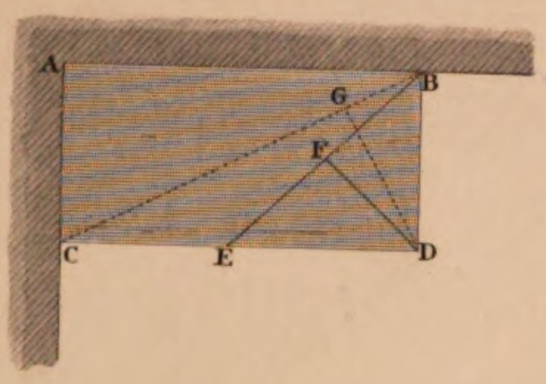
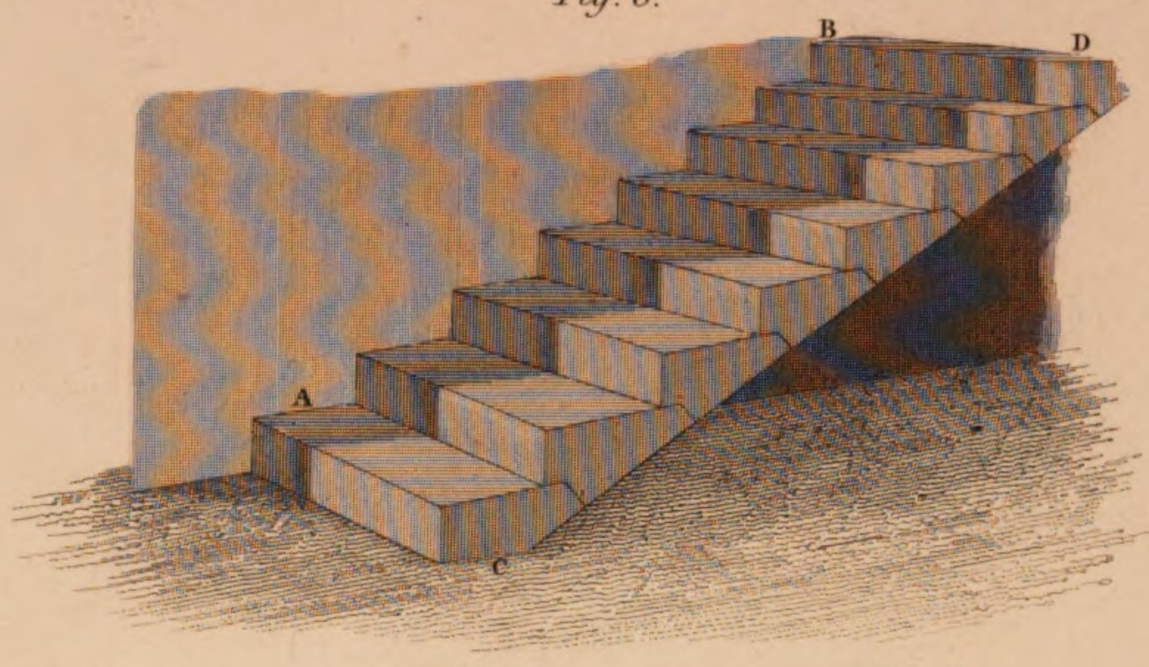


Fig. 6.



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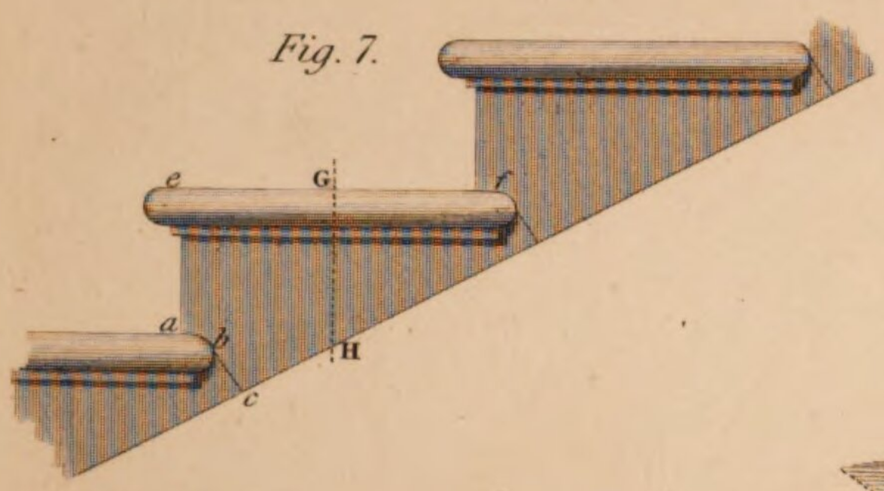

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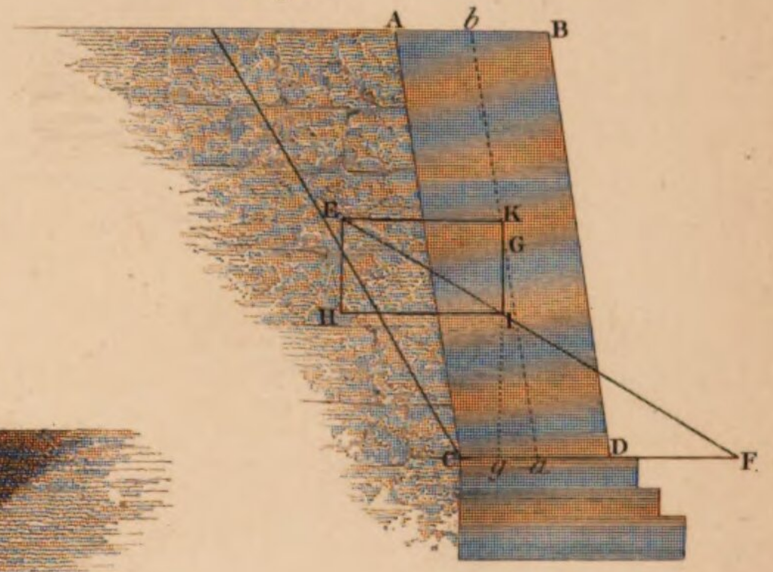

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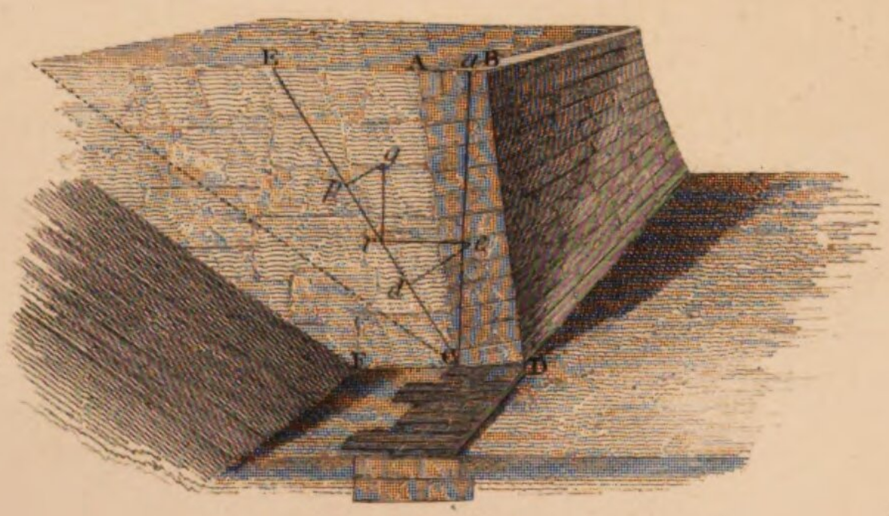

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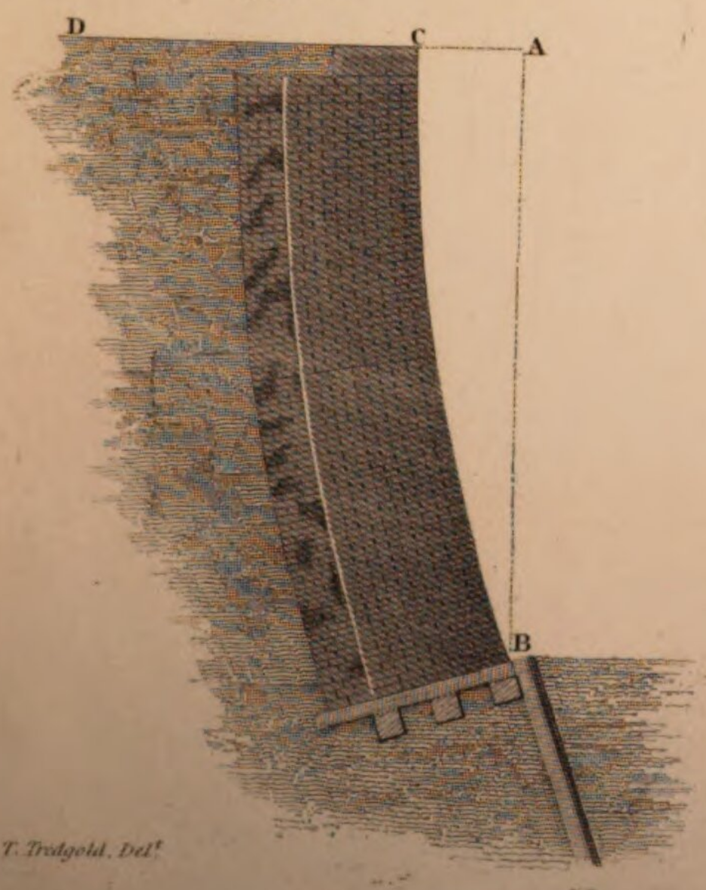

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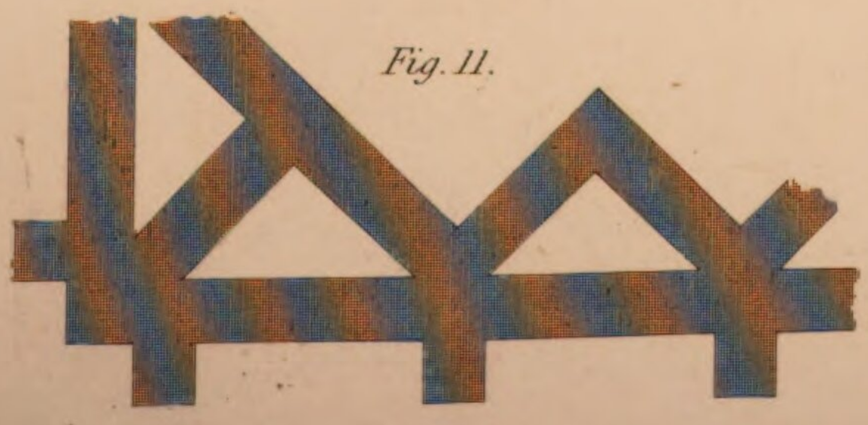

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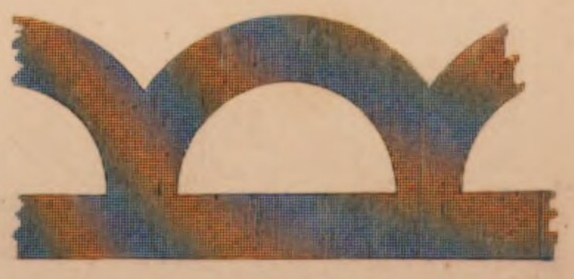

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Fig. 13.

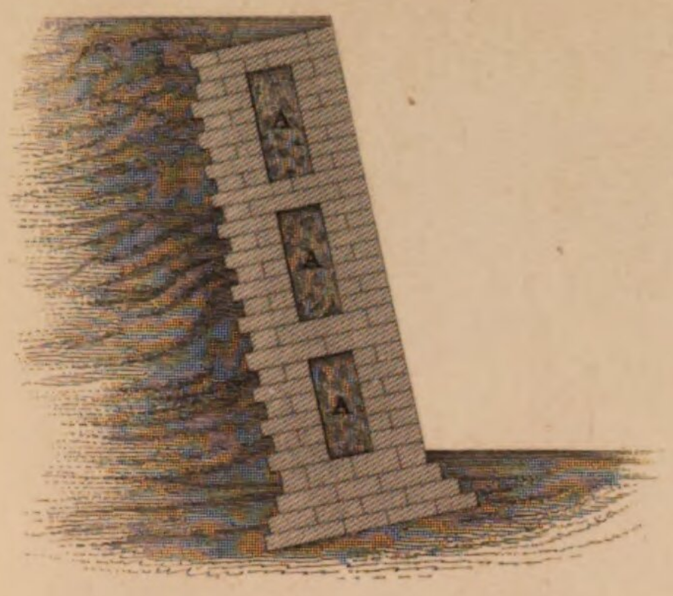
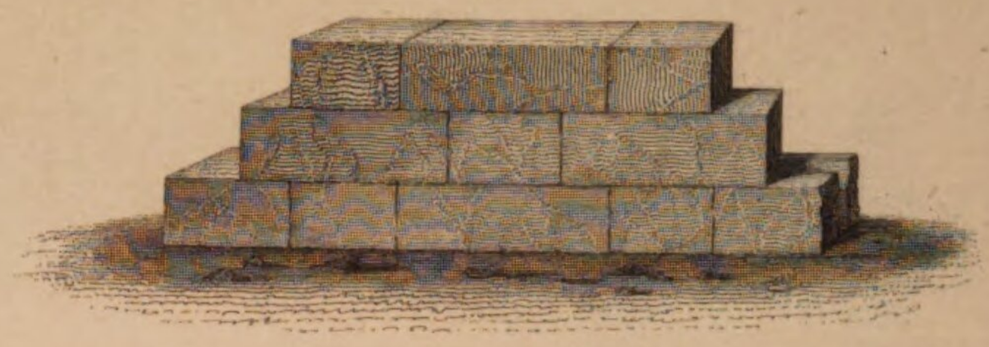


Fig. 14.

Fig. 15.



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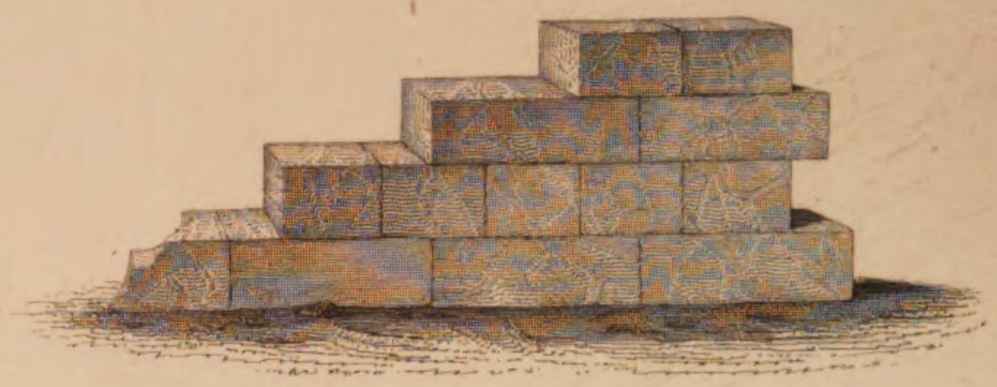

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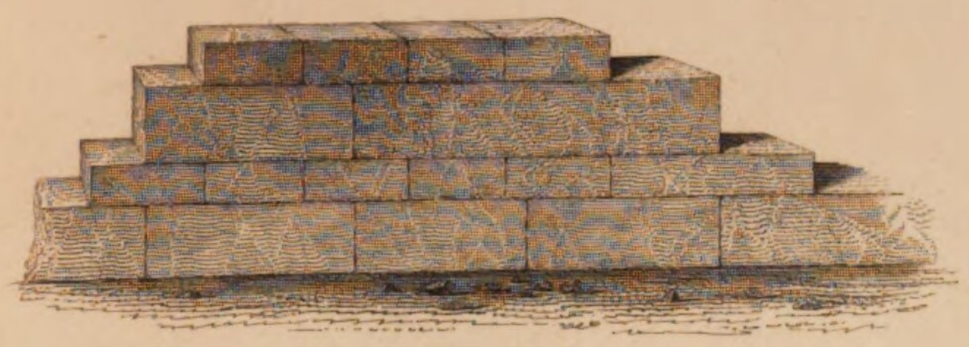

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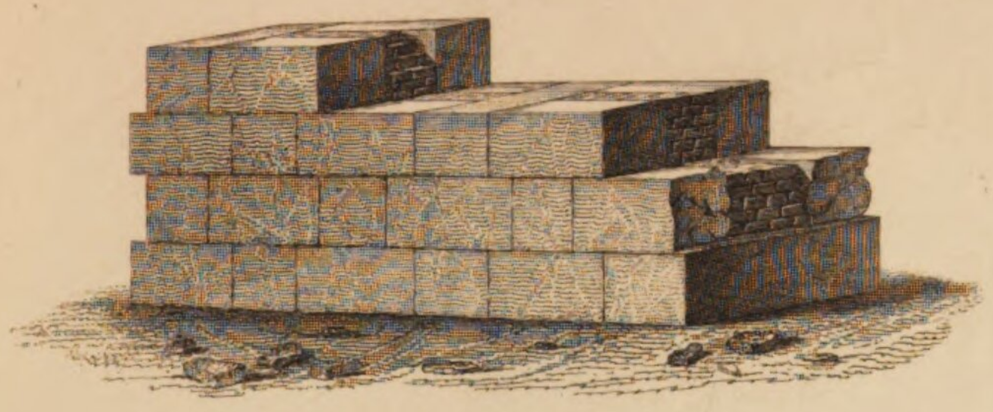

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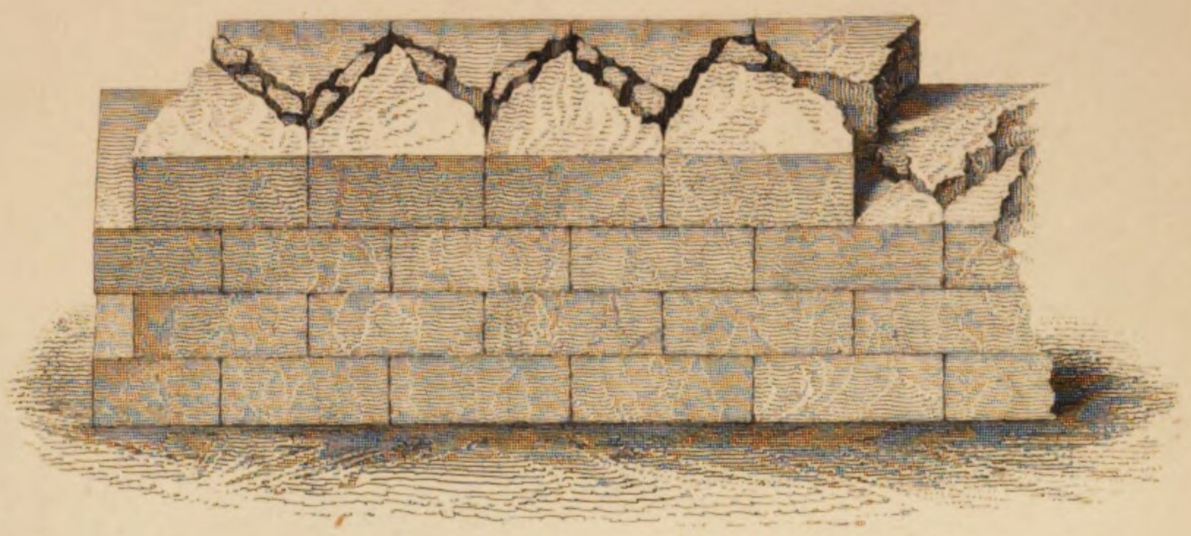

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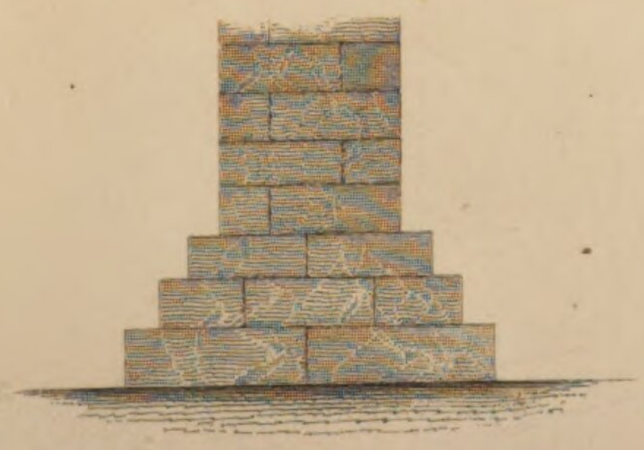

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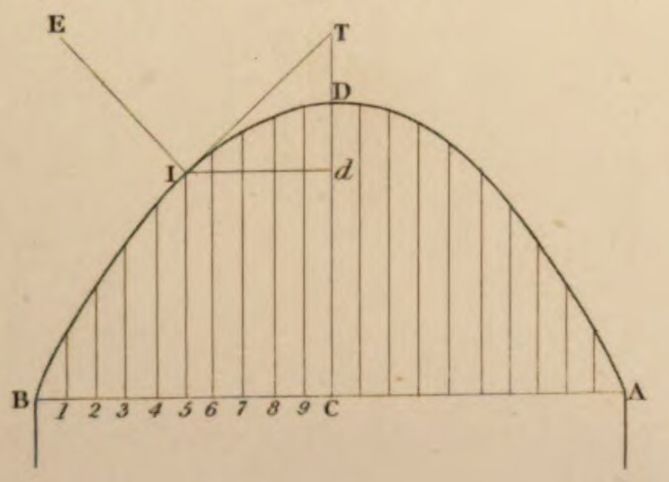

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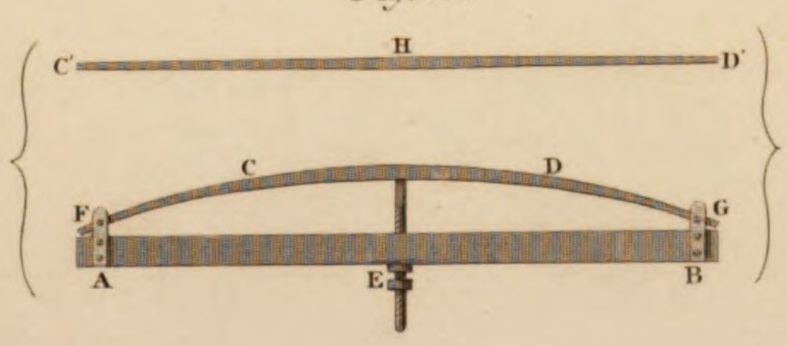

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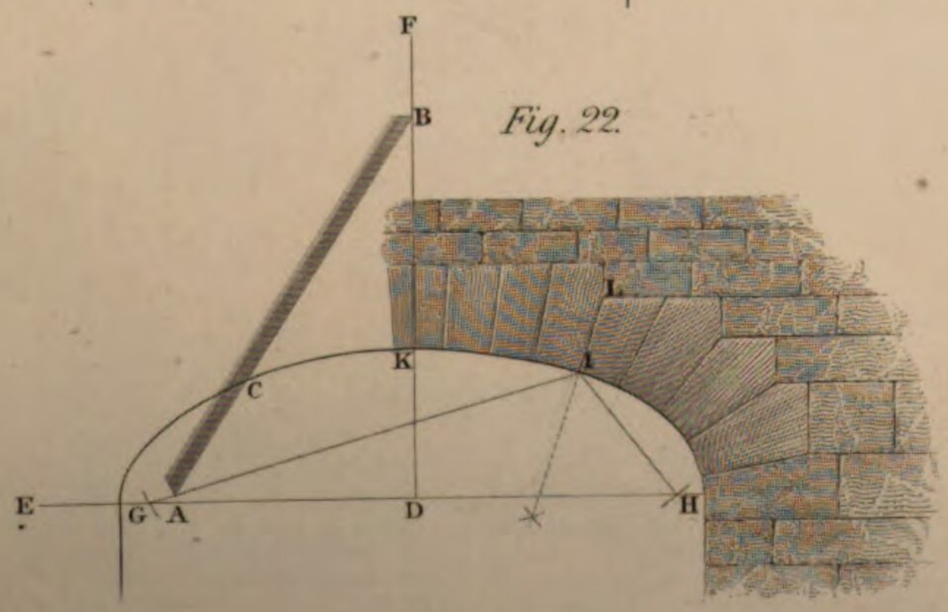

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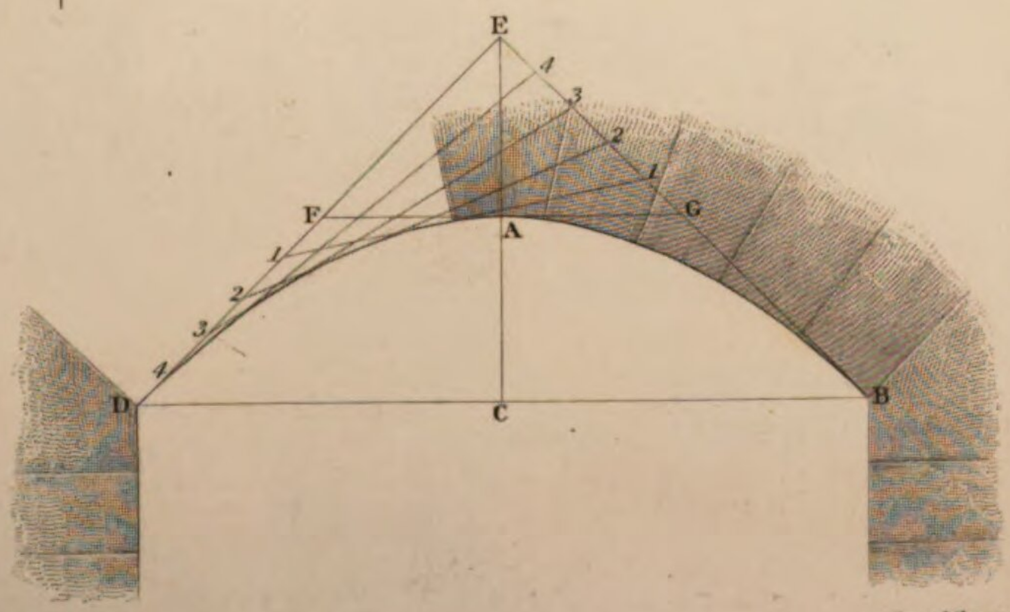

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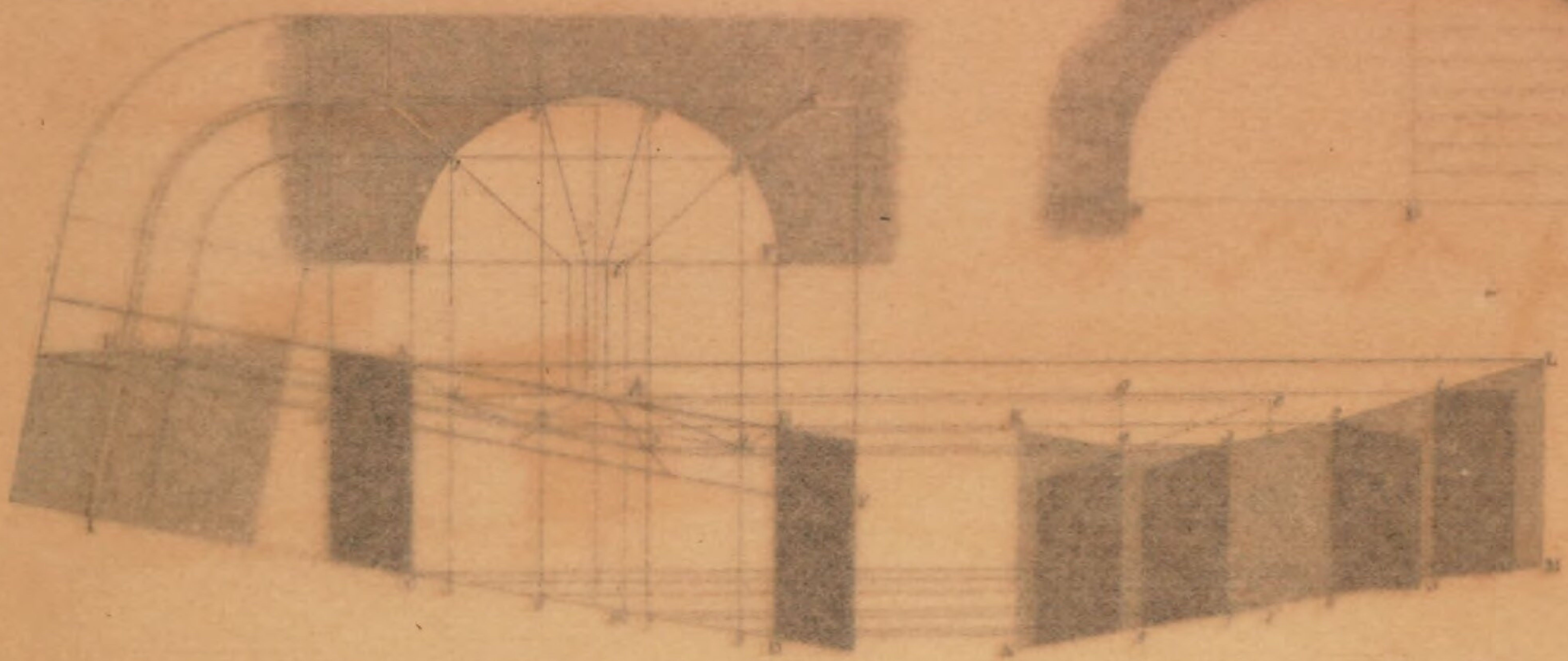
[illegible]

[illegible]

Fig. 27



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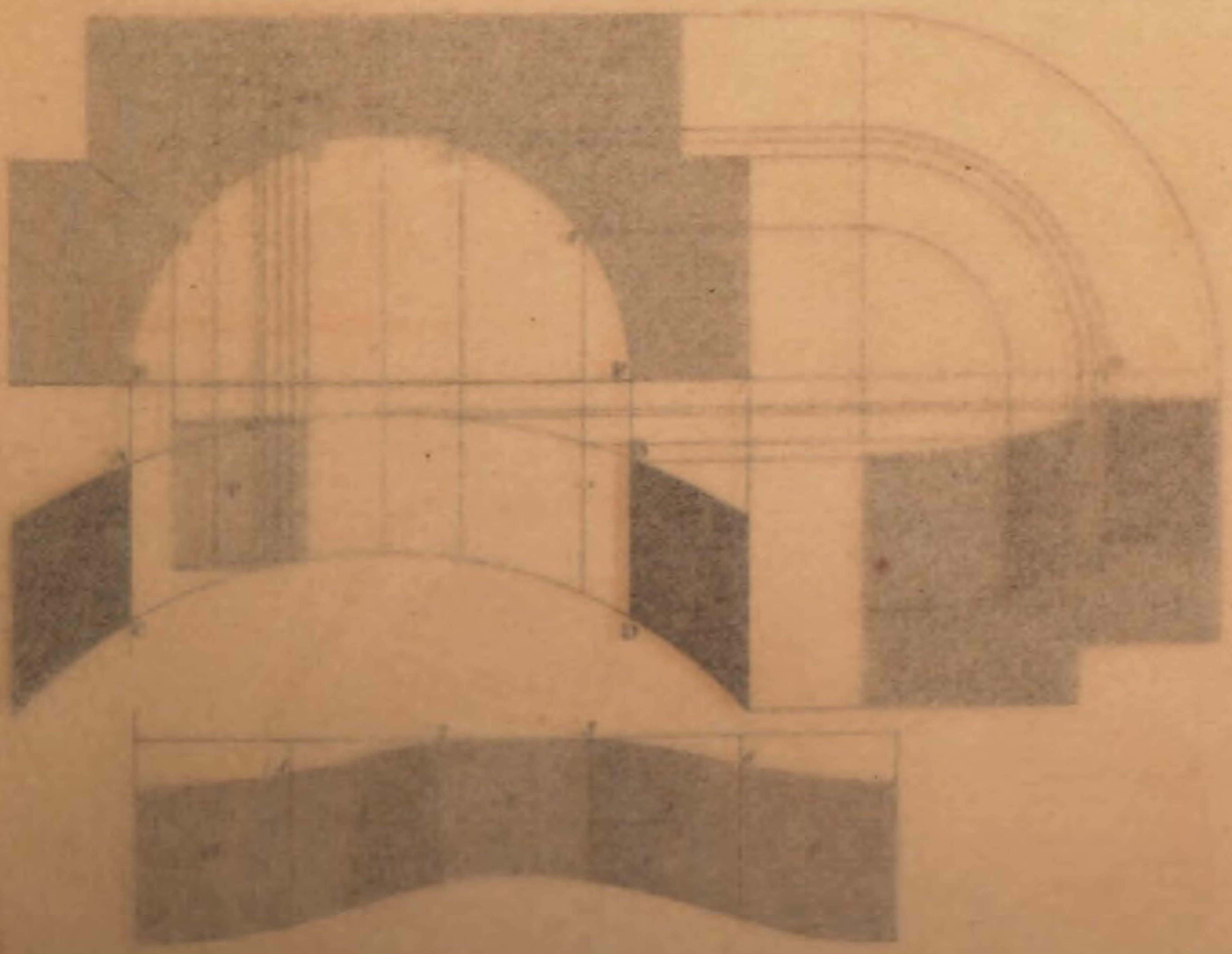

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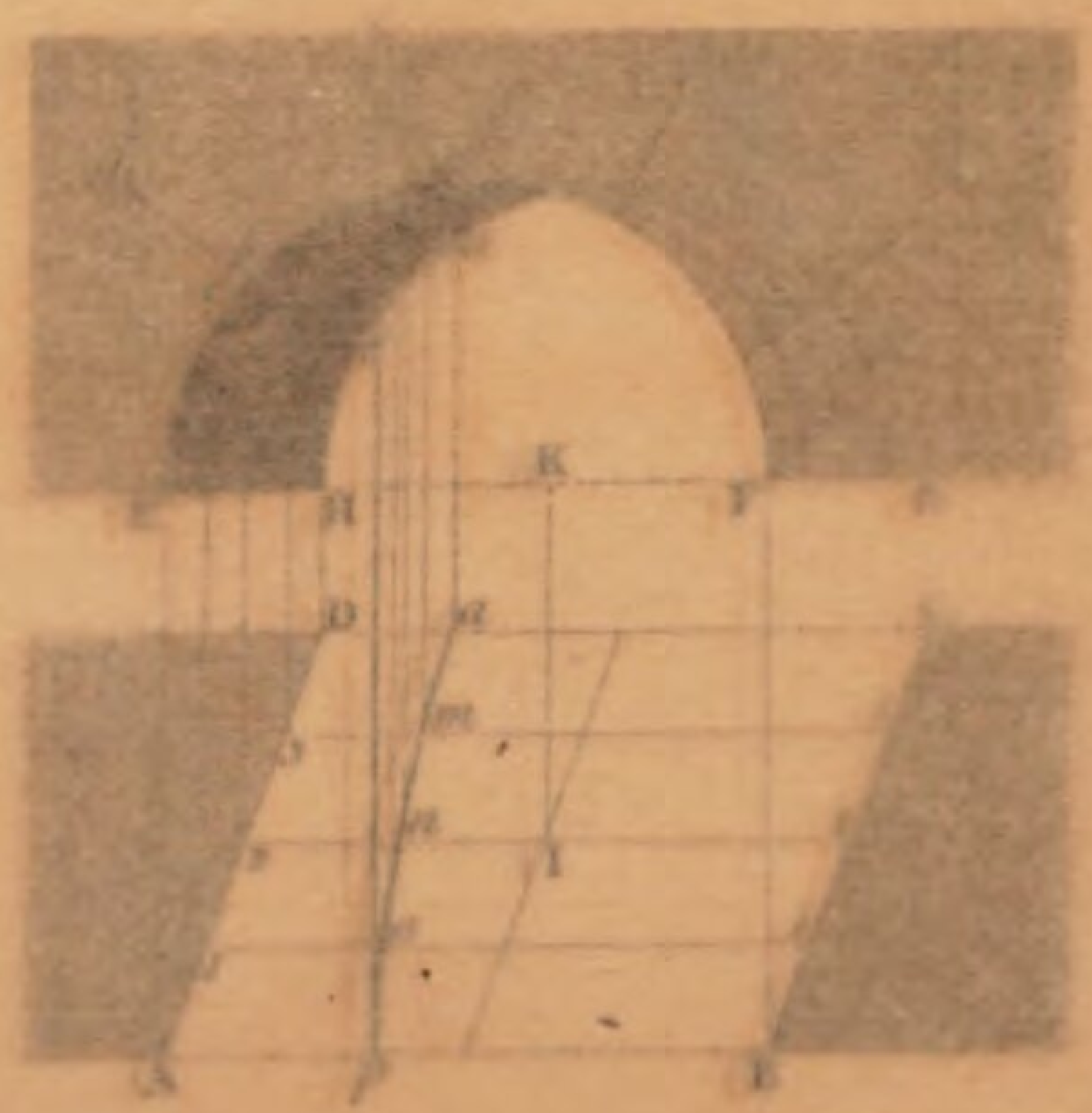

Fig. 30.

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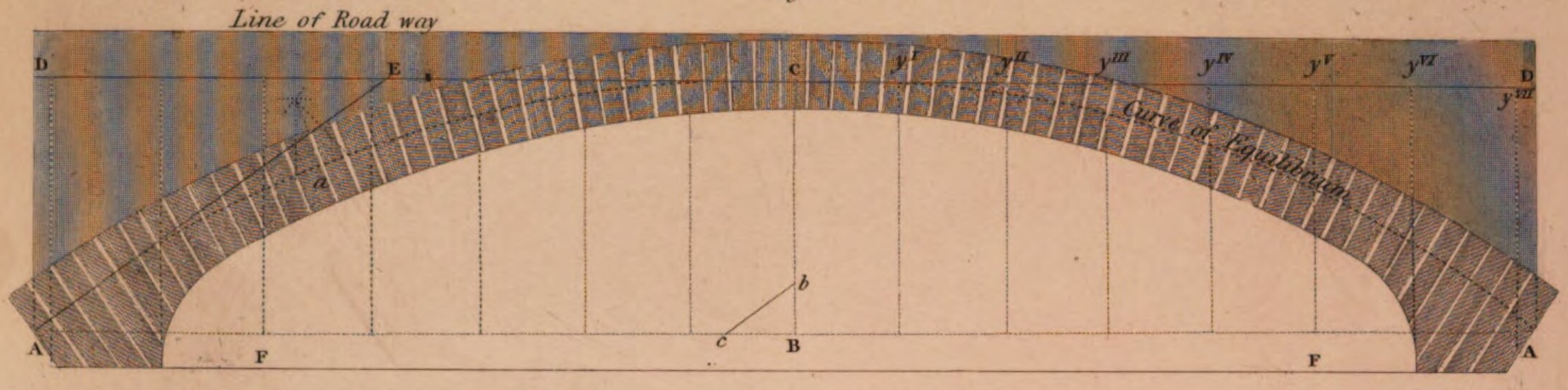
Fig. 26.



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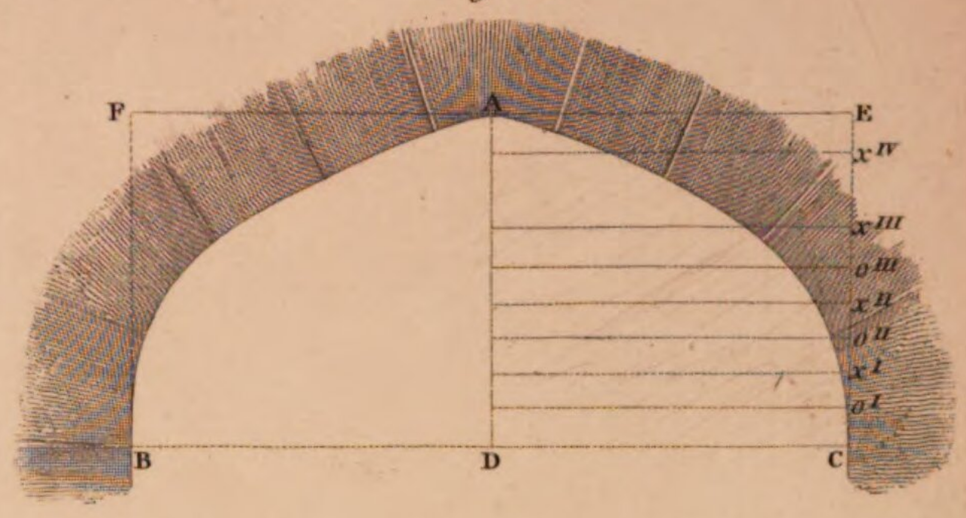

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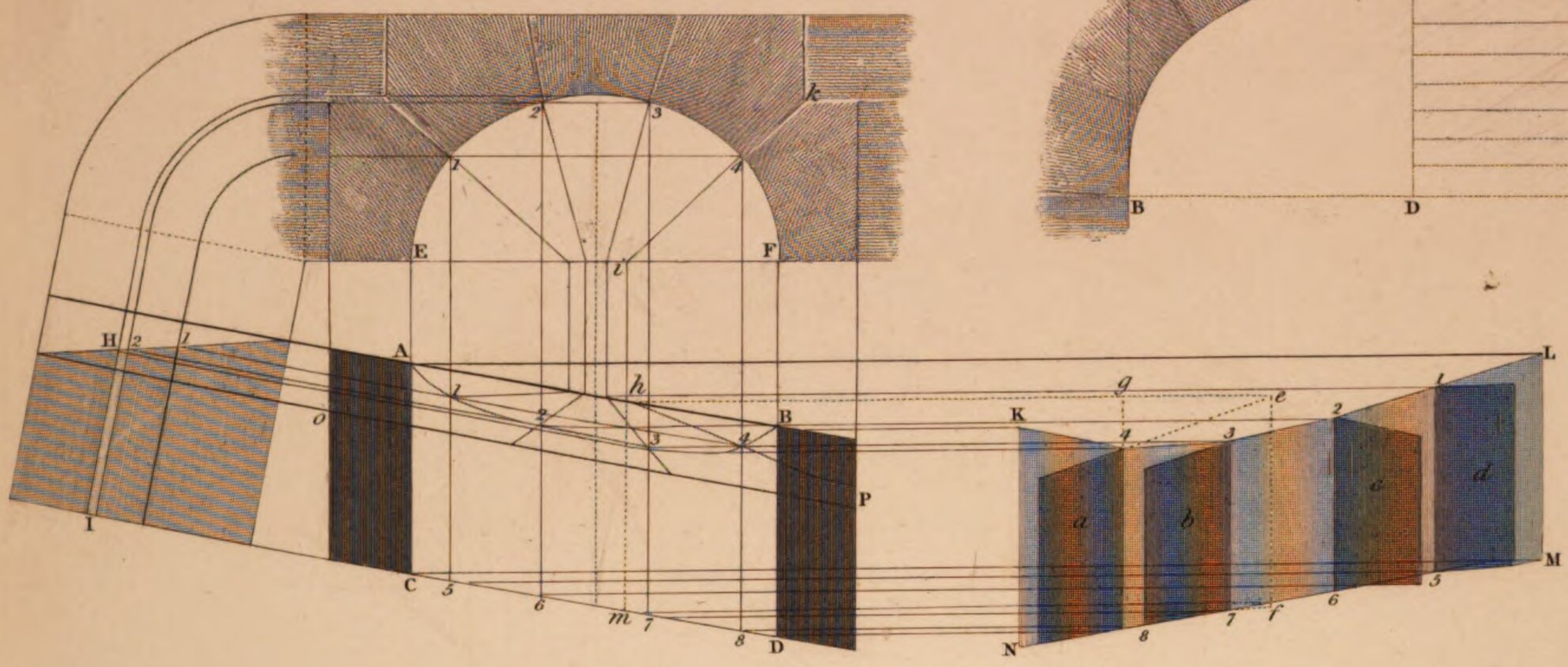

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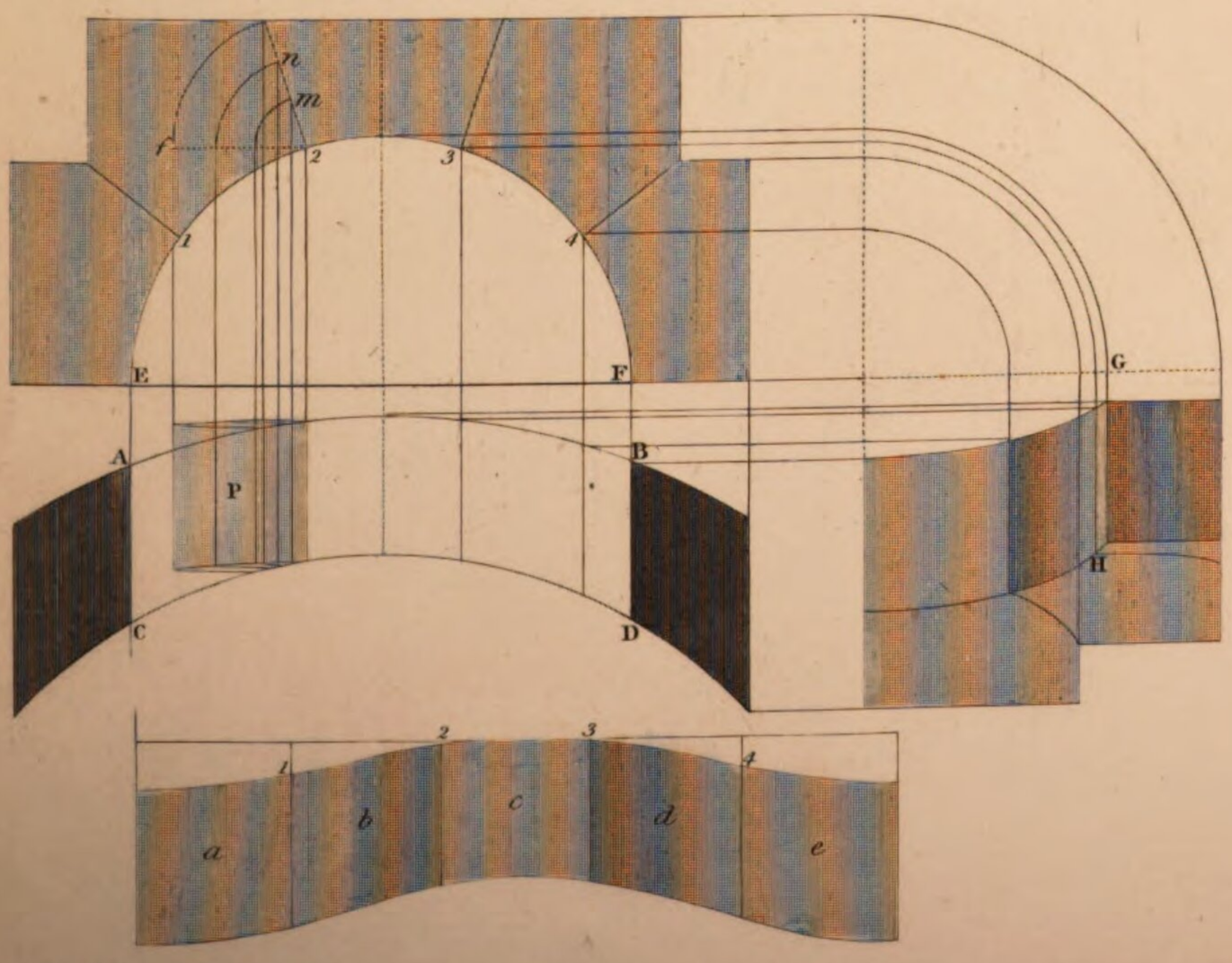

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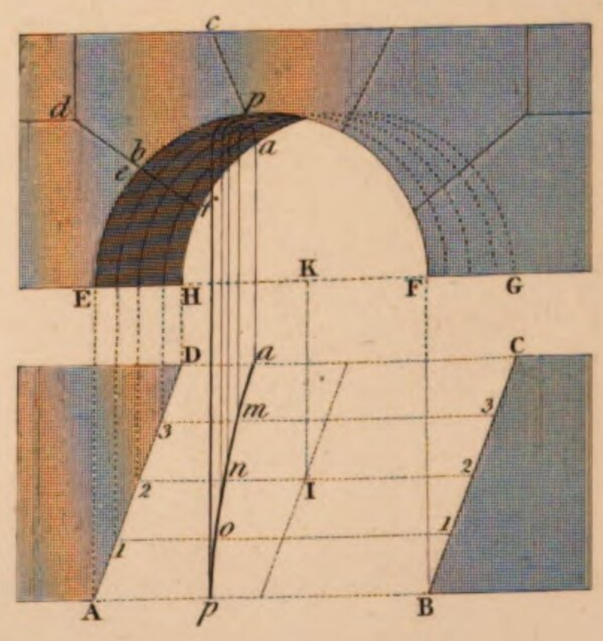

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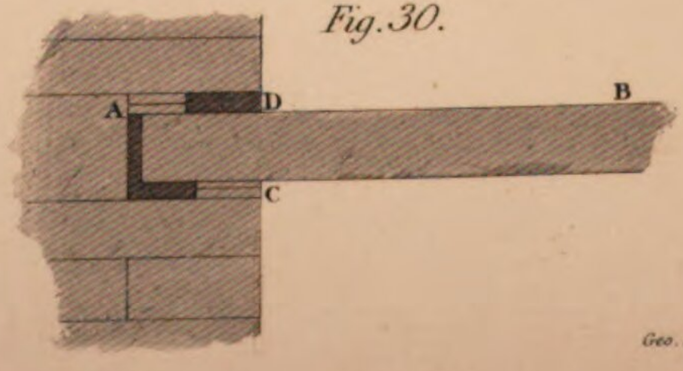

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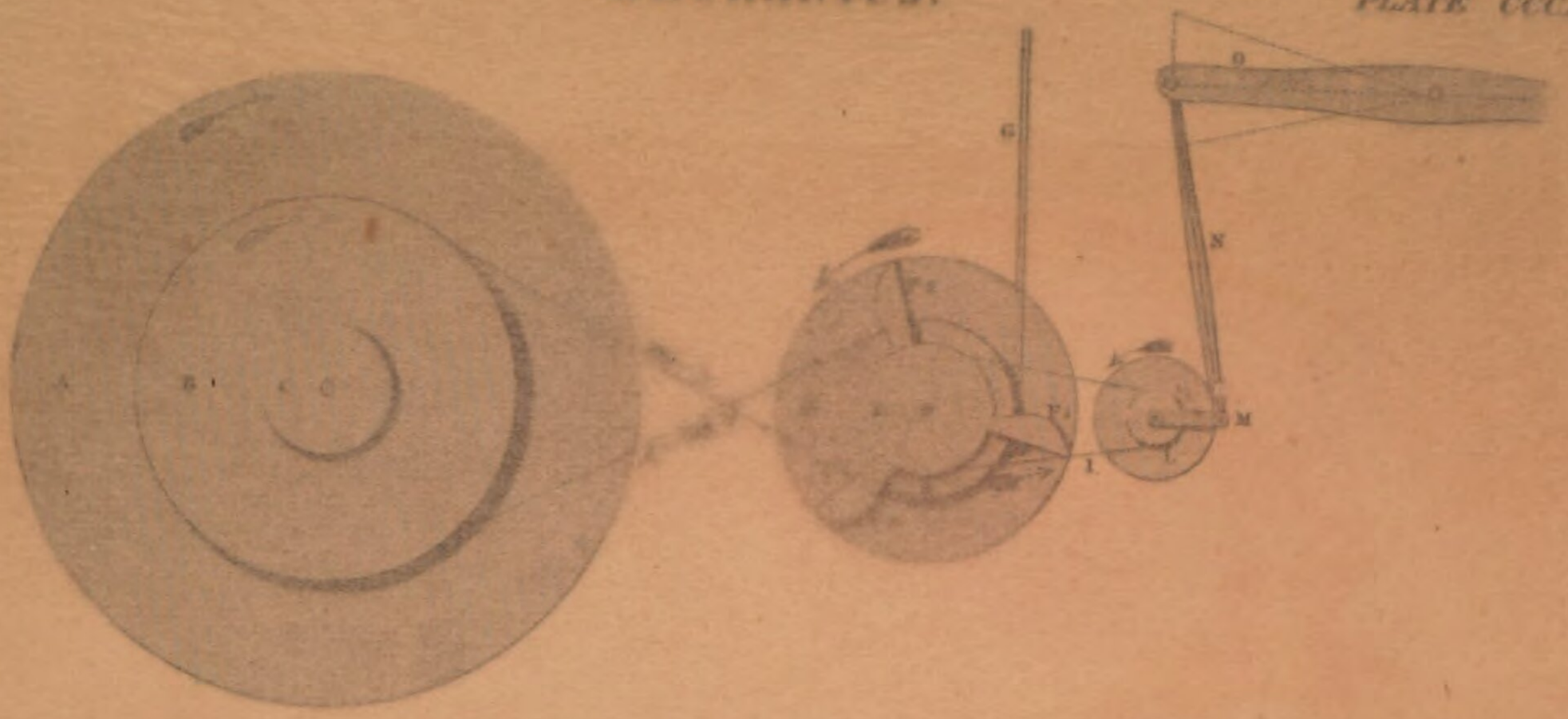

Explanation of the motion of the machine by means of signs.

Disposition of the pieces	*Moving wheel*	*Great wheel*	*Arbor of the Gr! wheel*	*Band*	*Small wheel*	*Arbor of the Canes*	*Canes*			*Snuffers*			*Great pulley*	*Band*	*Small pulley*	*Handle*	*Rod*	*Brass*
	A	B	C	H	D	E	F1	F2	F3	G1	G2	G3	K	I	L	M	S	O
Nature of the Motion.	○	○	○	|	○	○	○	○	○	↳	↳	↳	○	|	○	○	↳	⟆
Origin of the Motion	← +	← +	← +		← +	← +	← +	← +	← +	← +	← +	← +	← +		← +	← +	← +	← +
Epochs during a turn of the moving wheel. 0	⎫	⎫	⎫		⎫	⎫	⎫	⎫	⎫	⎫	⎫	⎫	⎫		⎫	⎫	⎫	⎫
1	⎪	⎪	⎪		⎪	⎪	⎪	⎪	⎪	⎪	⎪	⎪	⎪		⎪	⎪	⎪	⎪
2	⎪	⎪	⎪		⎪	⎪	⎪	⎪	⎪	⎪	⎪	⎪	⎪		⎪	⎪	⎪	⎪
3	⎪	⎪	⎪		⎪	⎪	⎪	⎪	⎪	⎪	⎪	⎪	⎪		⎪	⎪	⎪	⎪
4	⎭	⎭	⎭		⎭	⎭	⎭	⎭	⎭	⎭	⎭	⎭	⎭		⎭	⎭	⎭	⎭

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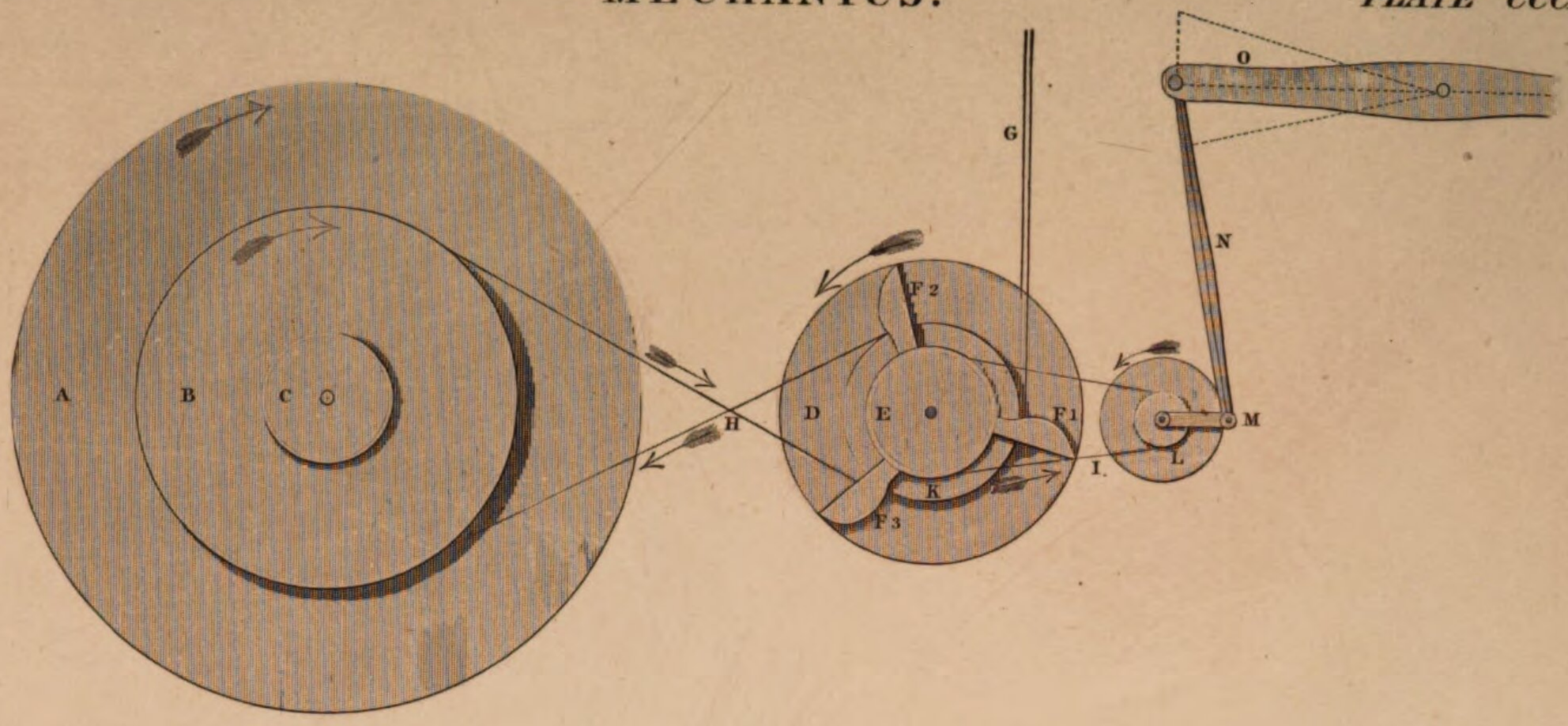

Explanation of the motion of the machine by means of signs.

Disposition of the pieces.	*Moving wheel* A	*Great wheel* B	*Arbor of the Gr.t wheel* C	*Band* H	*Small wheel* D	*Arbor of the Cams* E	*Cams* F1	F2	F3	*Stampers* G1	G2	G3	*Great pulley* K	*Band* I	*Small pulley* L	*Handle* M	*Rod* N	*Beam* O
Nature of the Motion.	○	○	○	|	○	○	○	○	○	ϟ	ϟ	ϟ	○	|	○	○	ϟ	ϟ
Origin of the Motion.	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←	←
Epochs during a turn of the moving wheel. 0	)	)	)	|	)	)	)	)	)	ϟ	ϟ	ϟ	)	|	)	)	ϟ	ϟ
1	)	)	)	|	)	)	)	)	)	ϟ	ϟ	ϟ	)	|	)	)	ϟ	ϟ
2	)	)	)	|	)	)	)	)	)	ϟ	ϟ	ϟ	)	|	)	)	ϟ	ϟ
3	)	)	)	|	)	)	)	)	)	ϟ	ϟ	ϟ	)	|	)	)	ϟ	ϟ
4	)	)	)	|	)	)	)	)	)	ϟ	ϟ	ϟ	)	|	)	)	ϟ	ϟ
5	)	)	)	|	)	)	)	)	)	ϟ	ϟ	ϟ	)	|	)	)	ϟ	ϟ
6	)	)	)	|	)	)	)	)	)	ϟ	ϟ	ϟ	)	|	)	)	ϟ	ϟ

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Fig. 5.

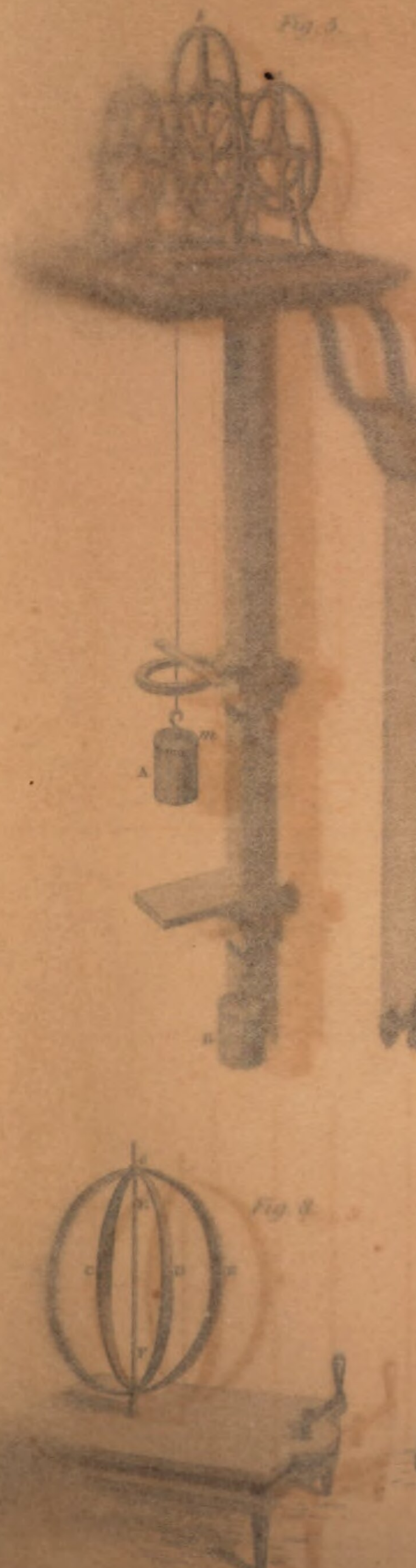


Fig. 4.

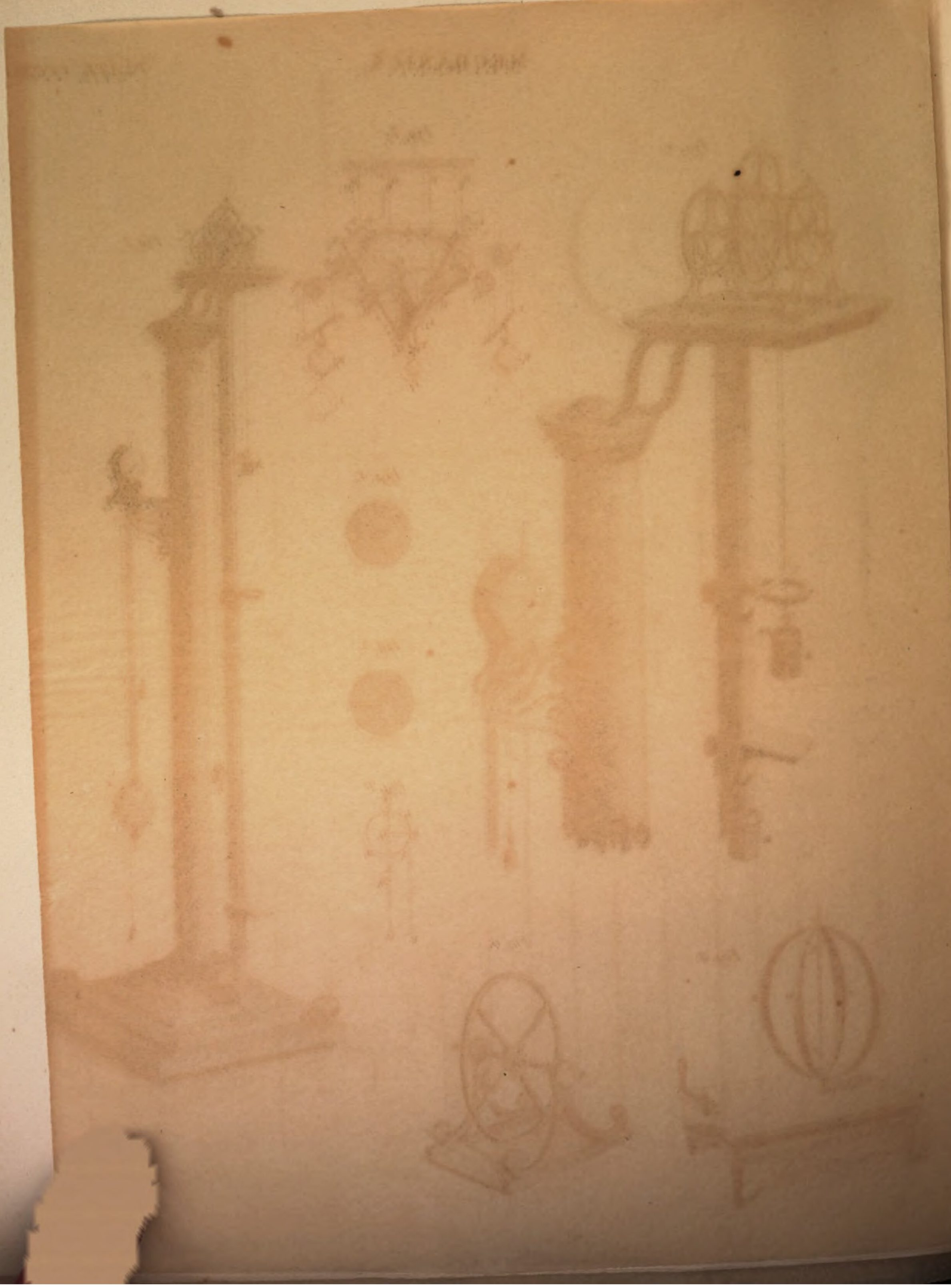
Fig. 1.

Fig. 3.

Fig. 7.

Fig. 6.

Fig. 8.



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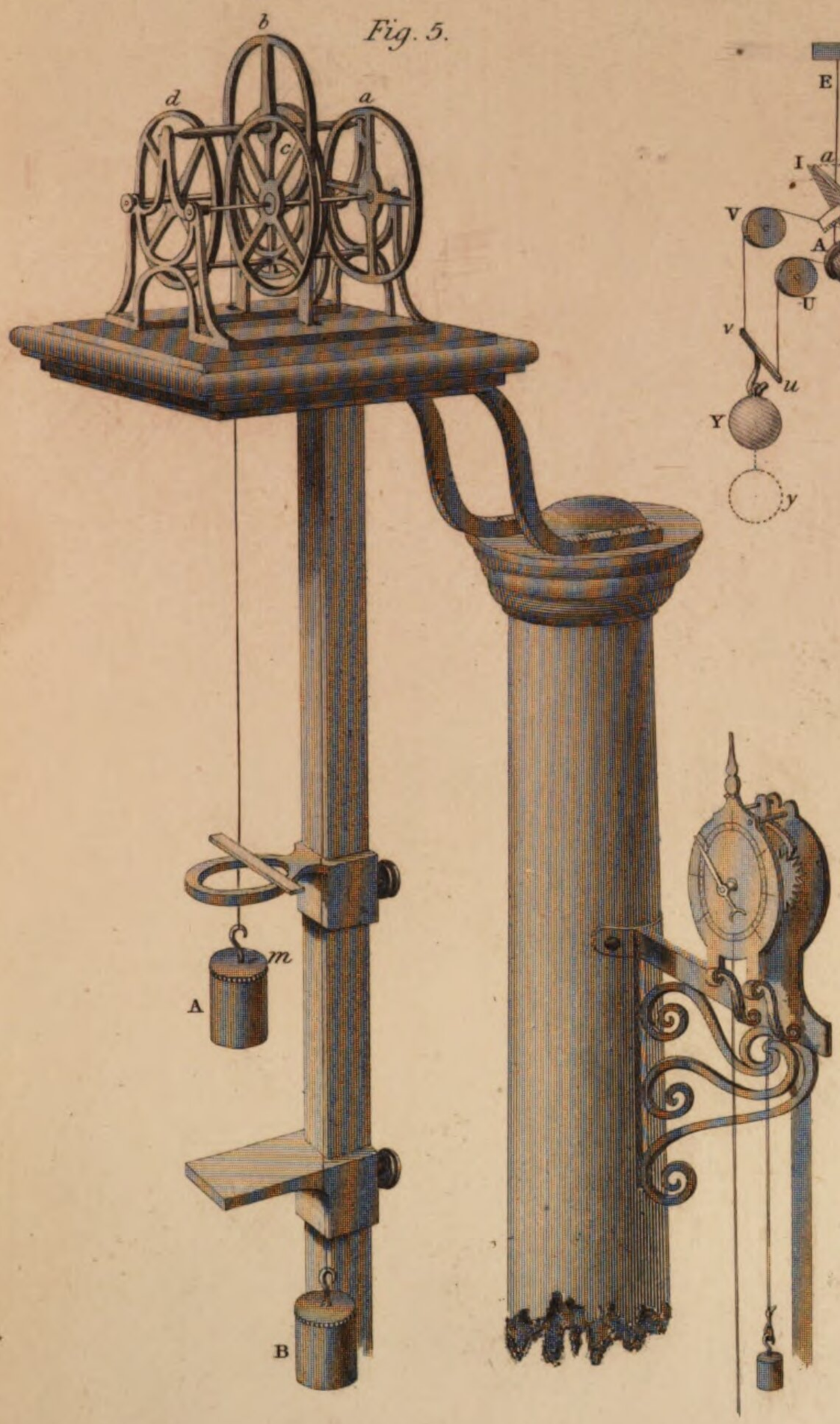

Fig. 7.

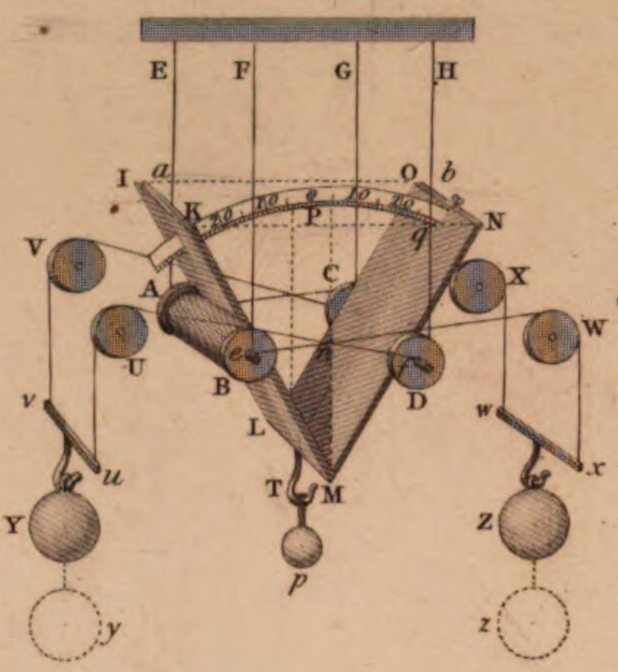

Fig. 4.

Fig. 3.

Fig. 2.

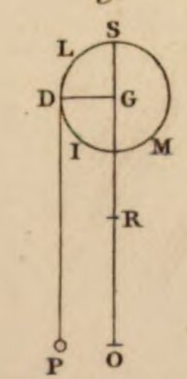

Fig. 1.

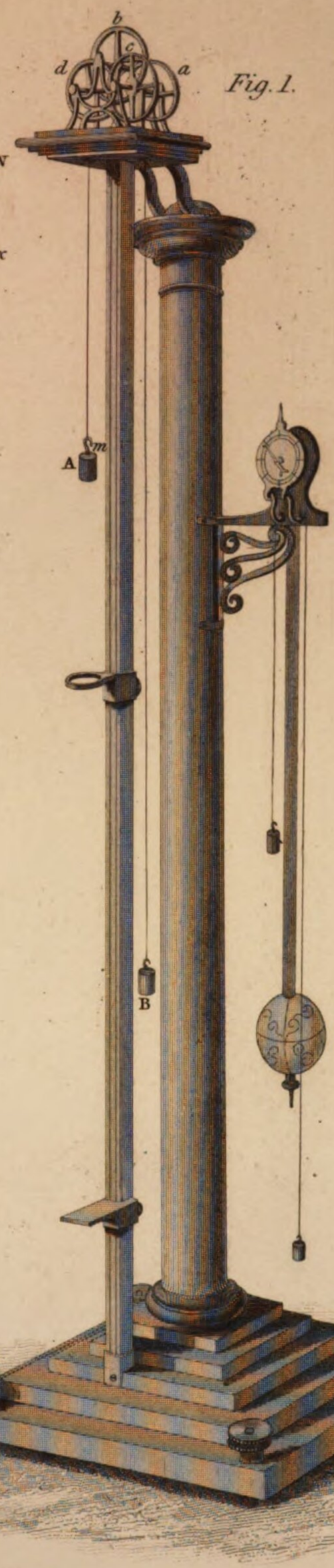

Fig. 8.

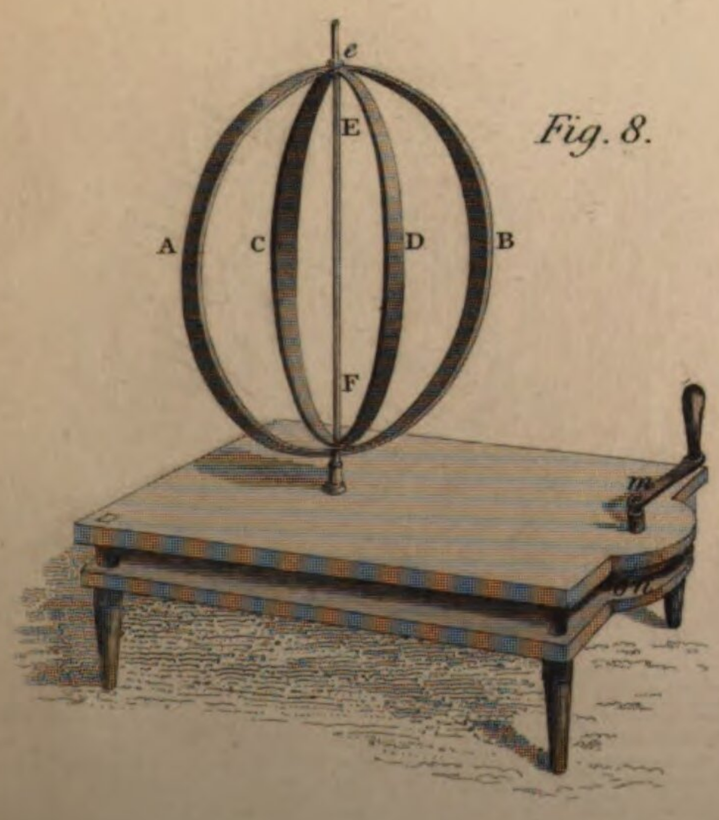

Fig. 6.

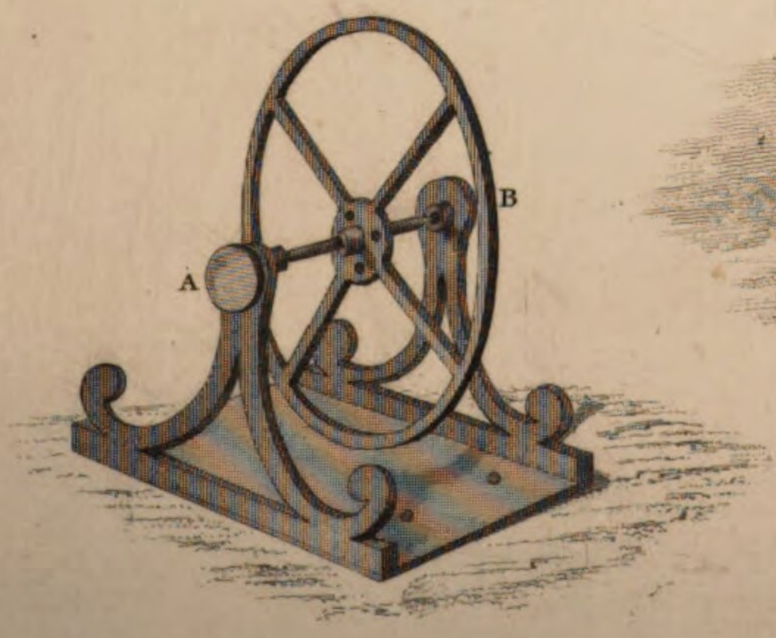

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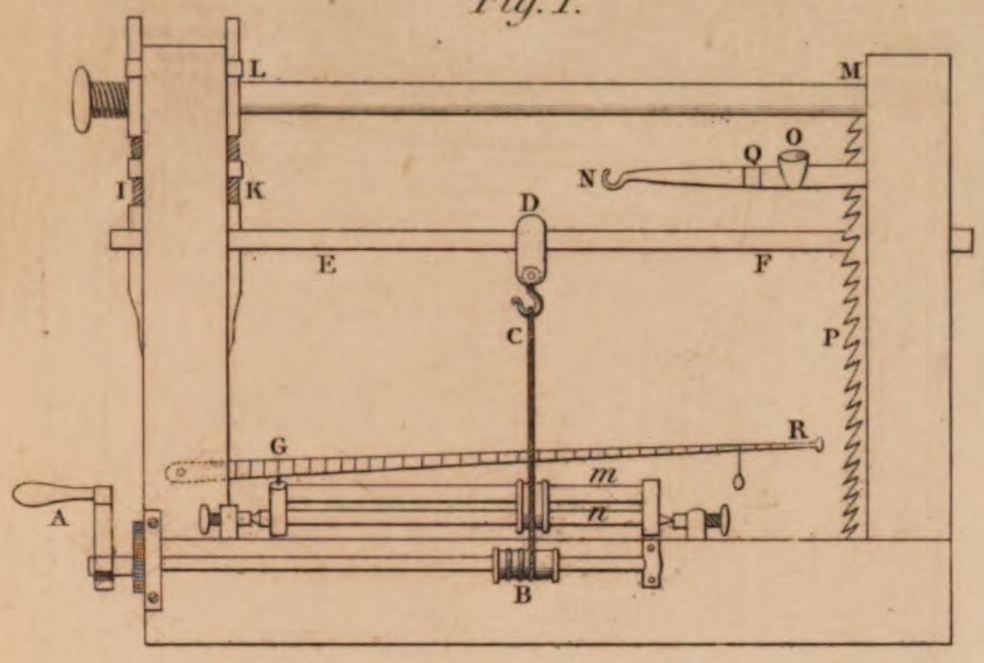
Fig. 1.



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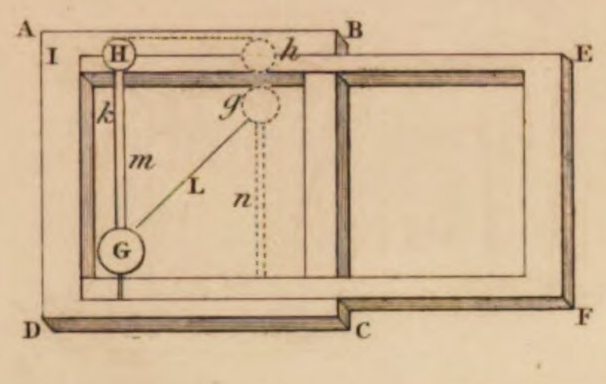

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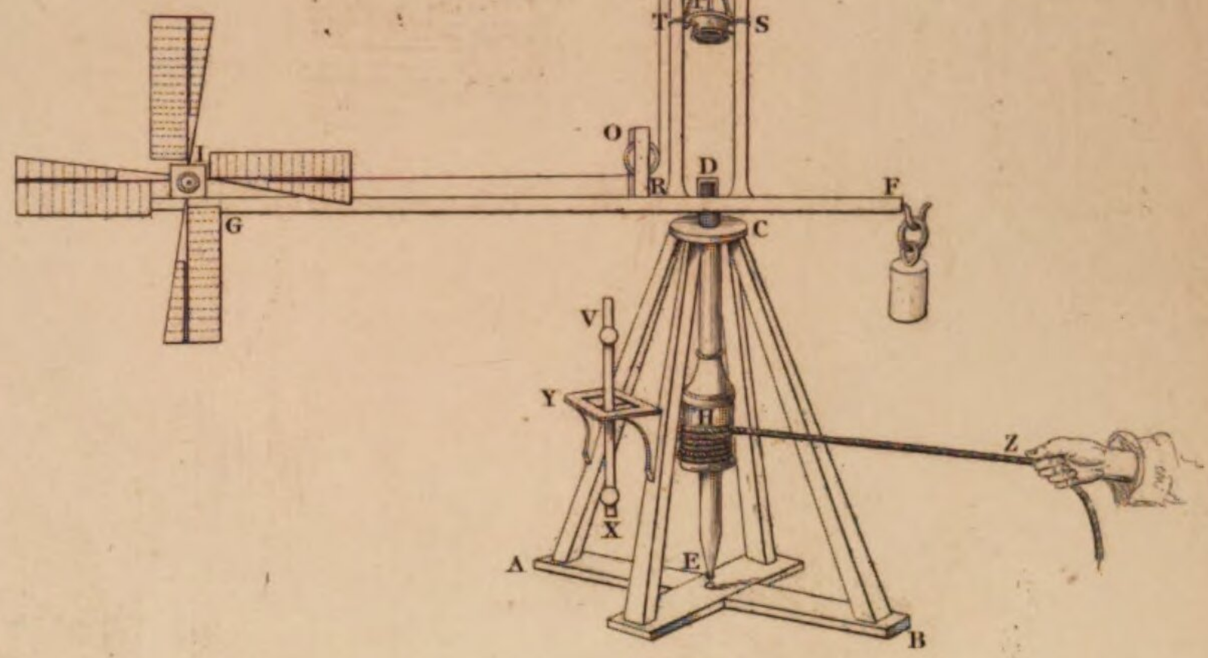


Fig. 4.

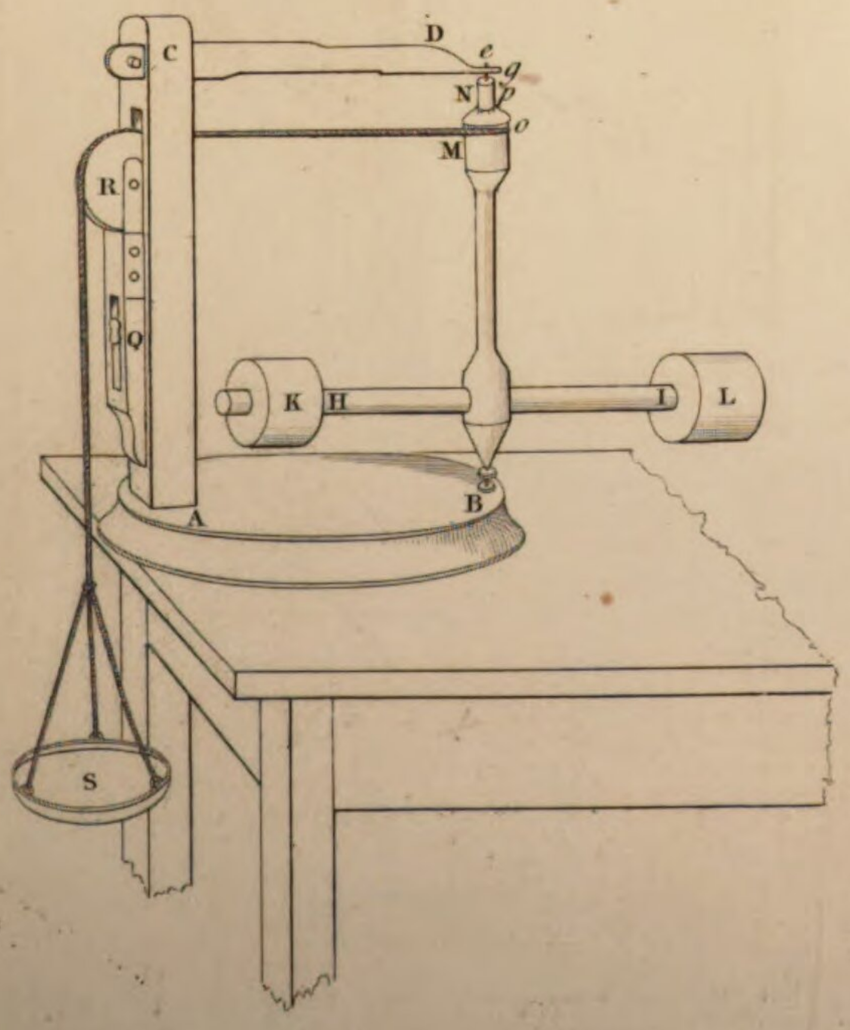


Fig. 5.

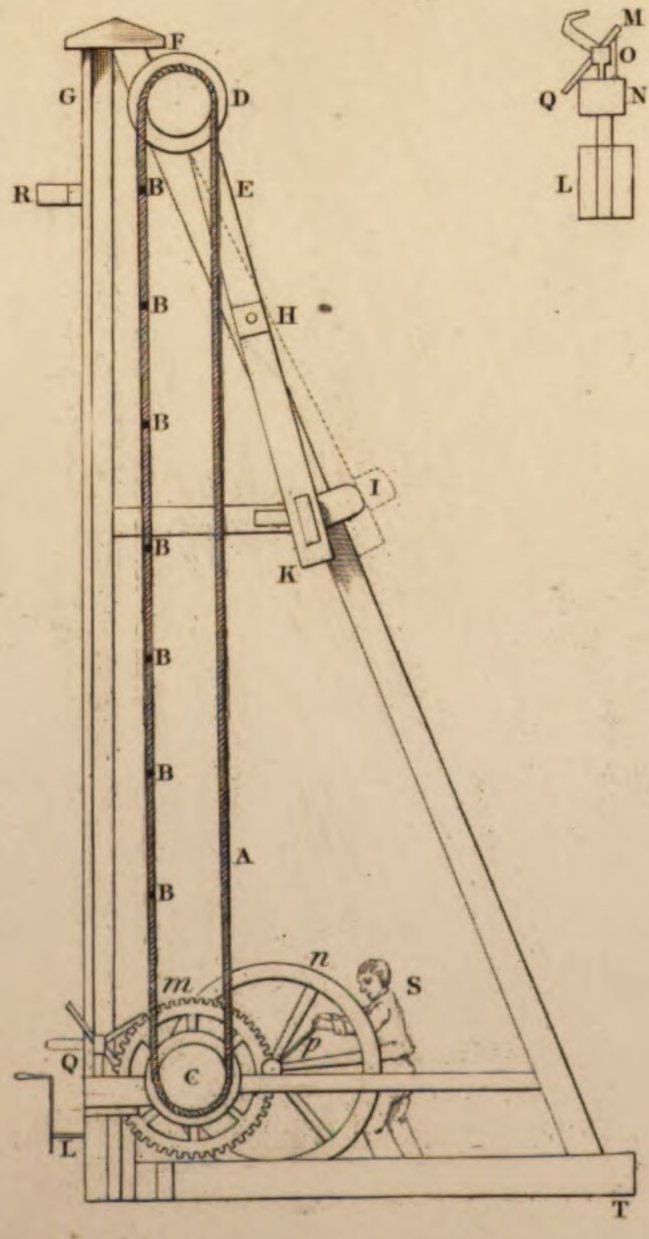
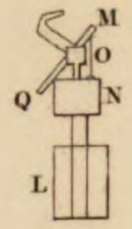


Fig. 7.



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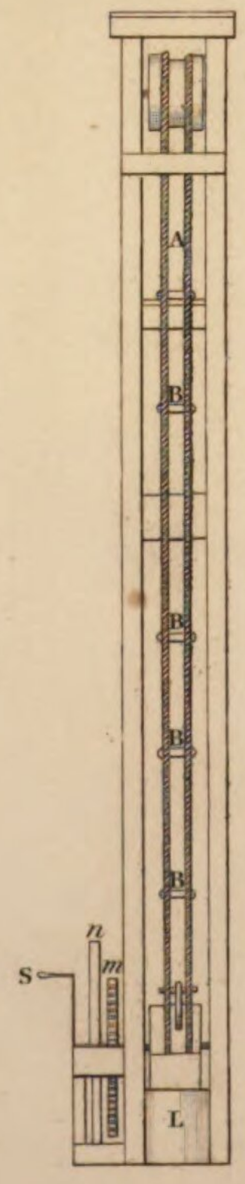

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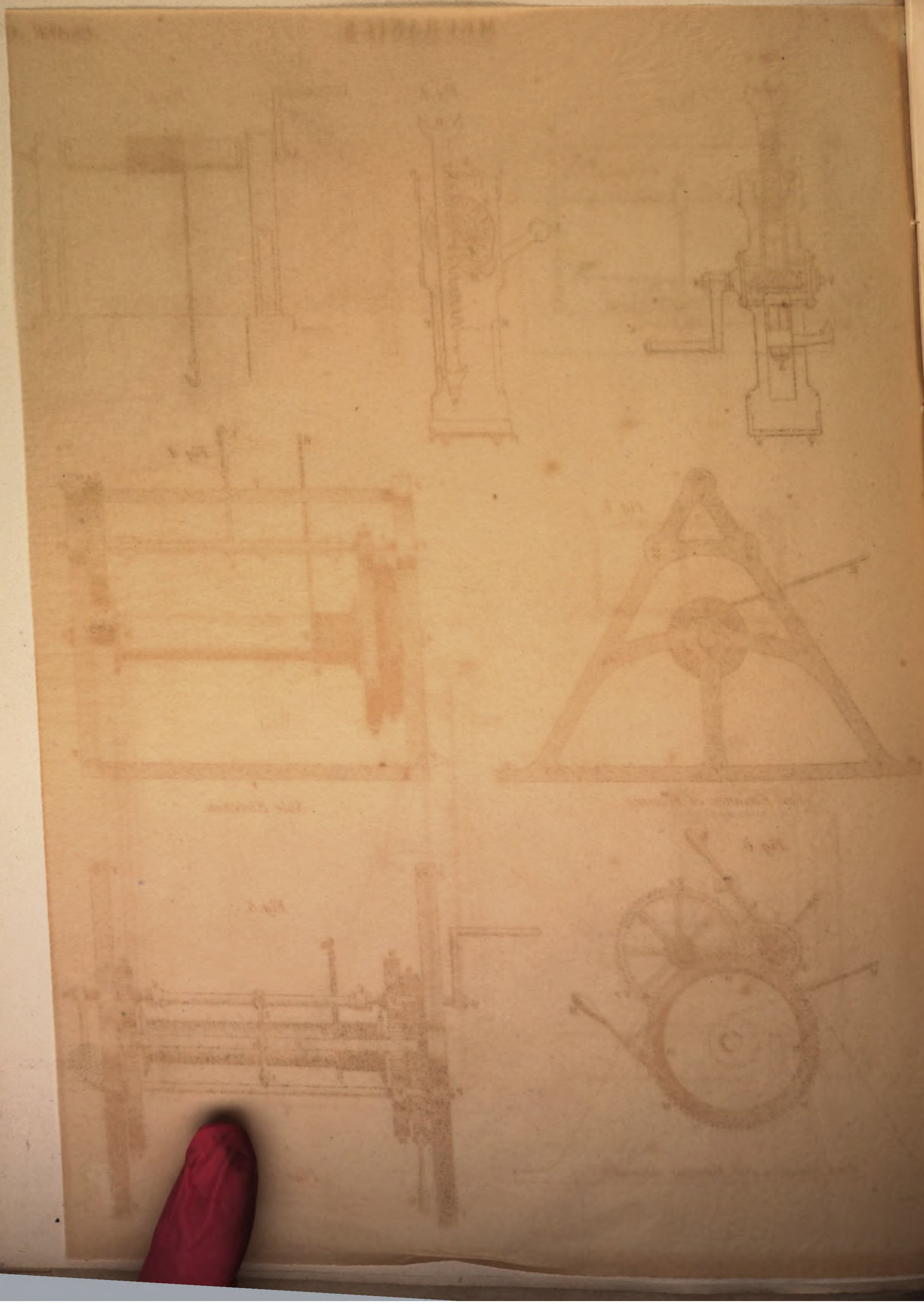

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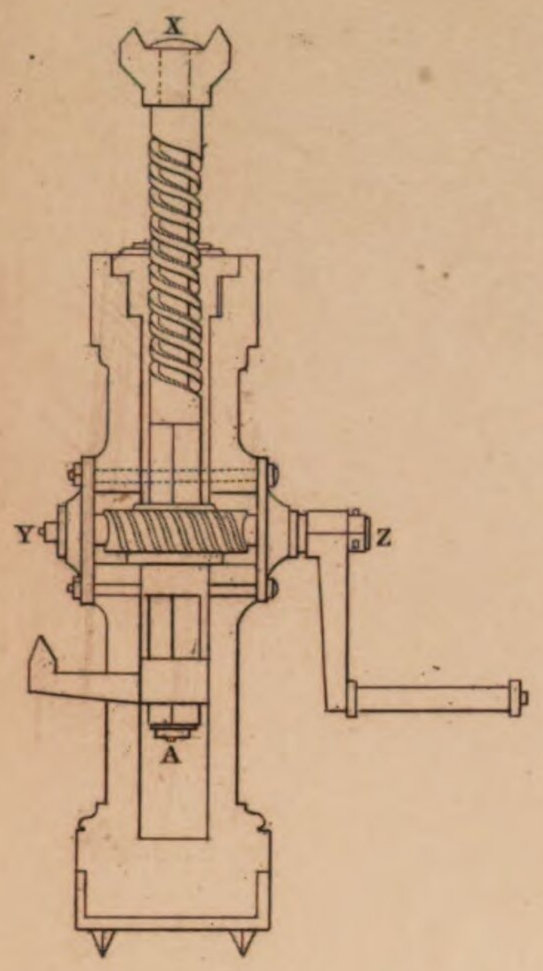
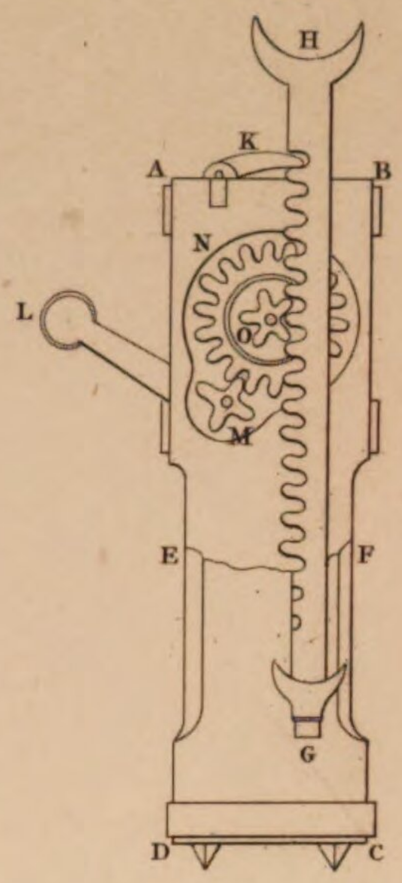


Fig. 1.



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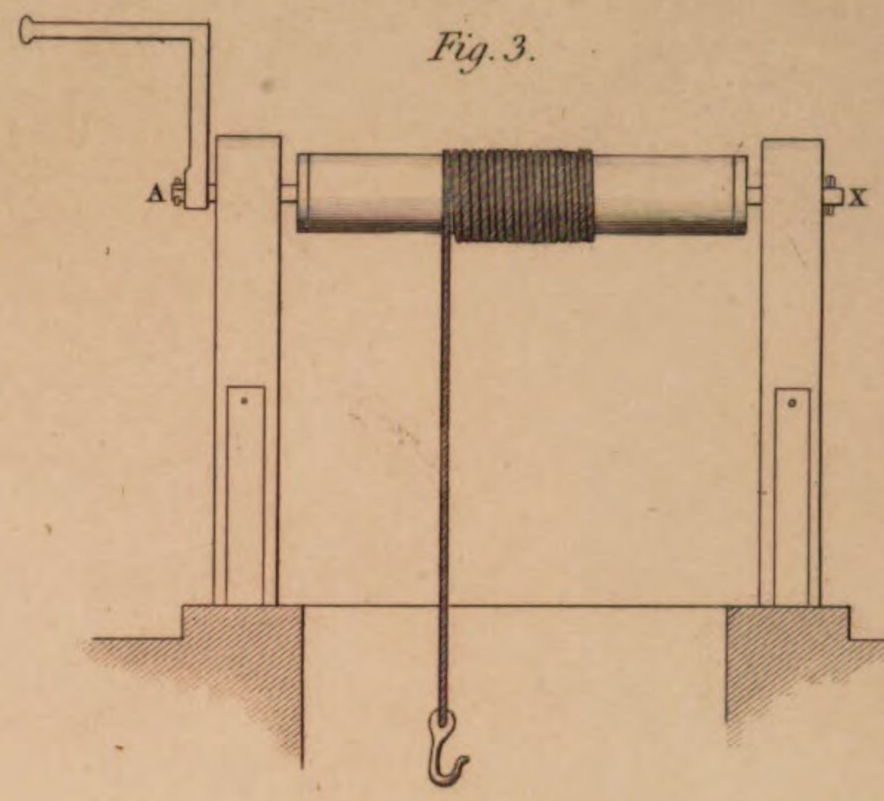

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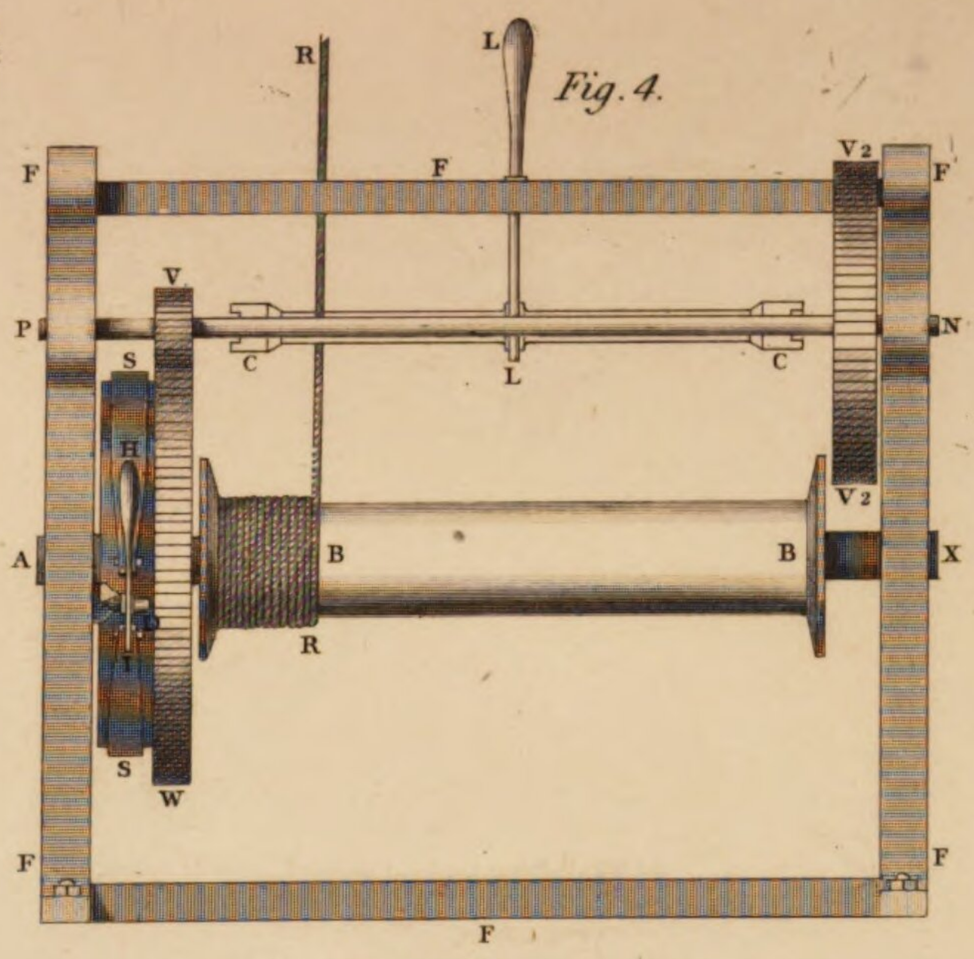

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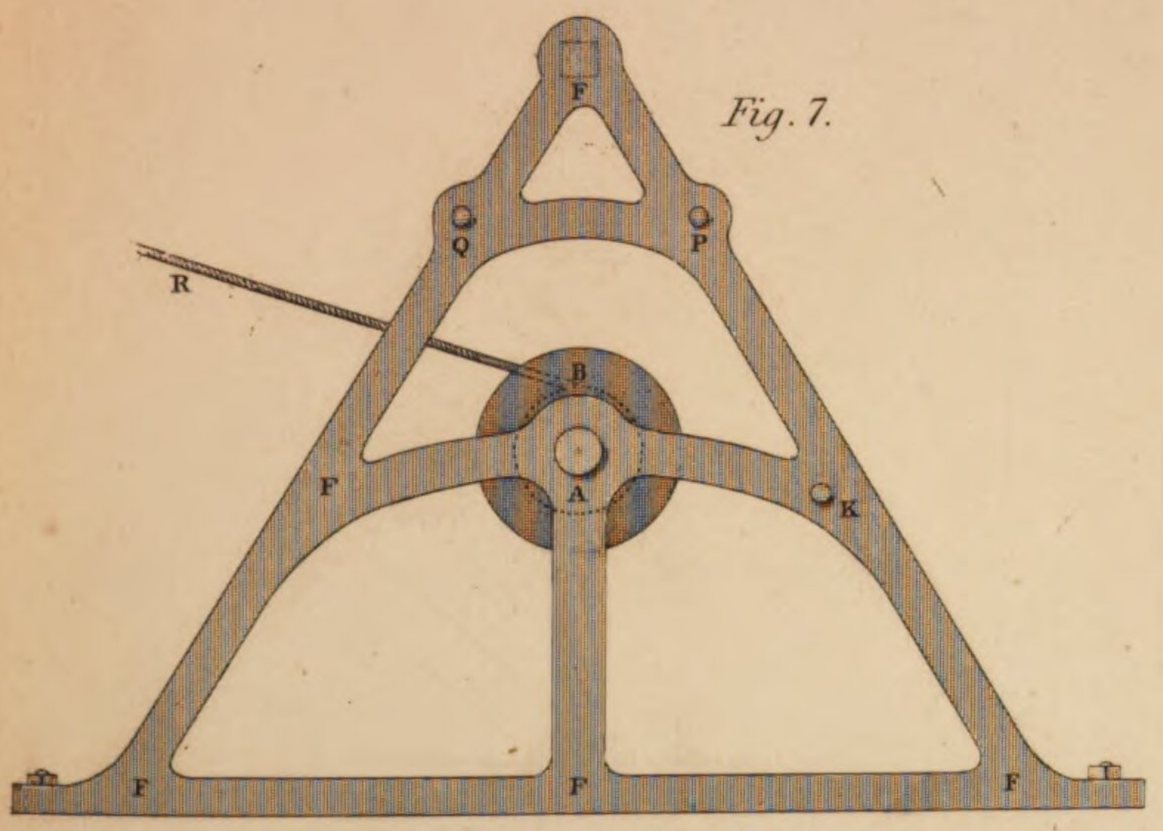
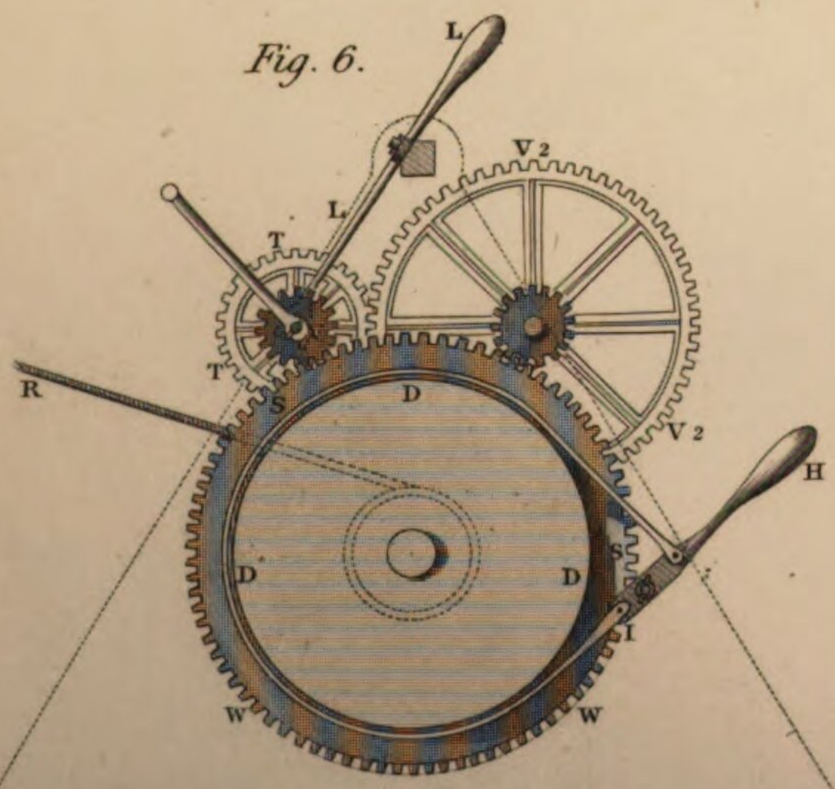


End Elevation of Framing.

Side Elevation.

Fig. 6.



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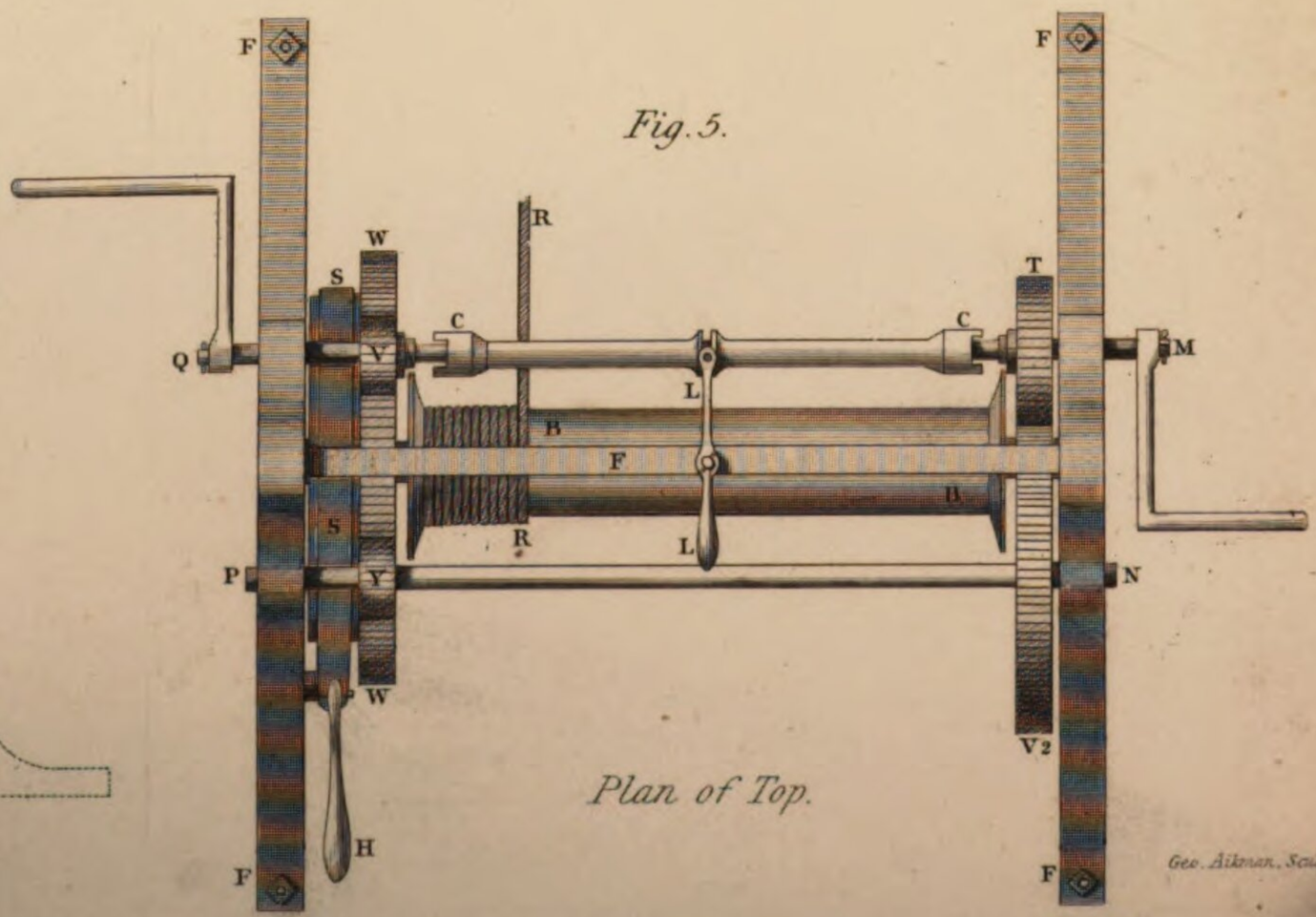

Plan of Top.

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Geo. Aikman, Sculp.t

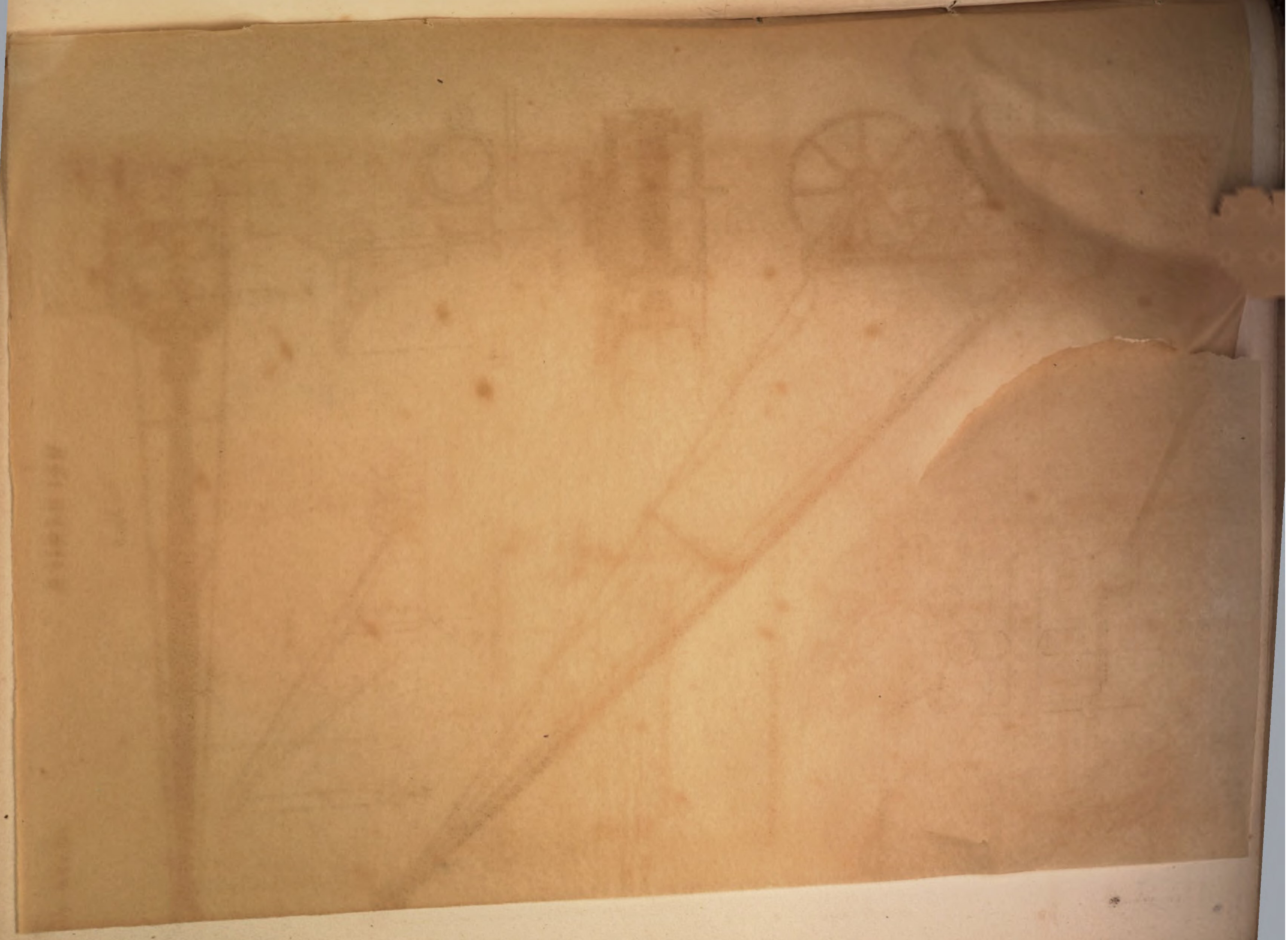
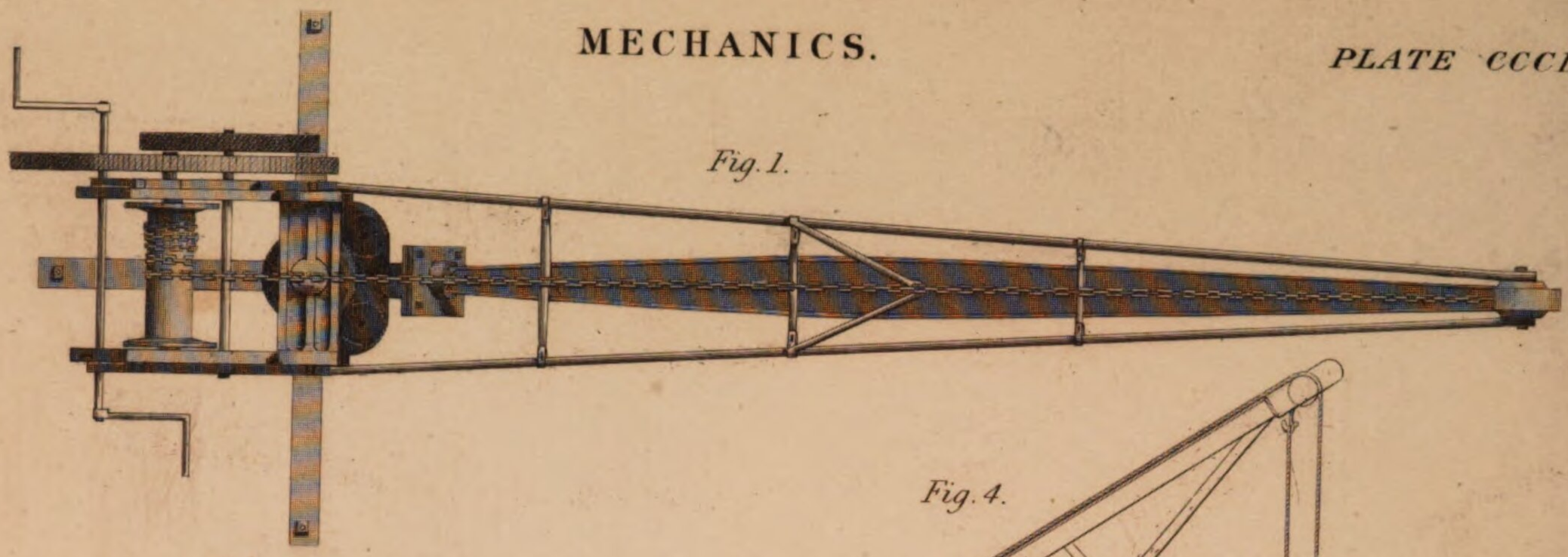


Fig. 1.



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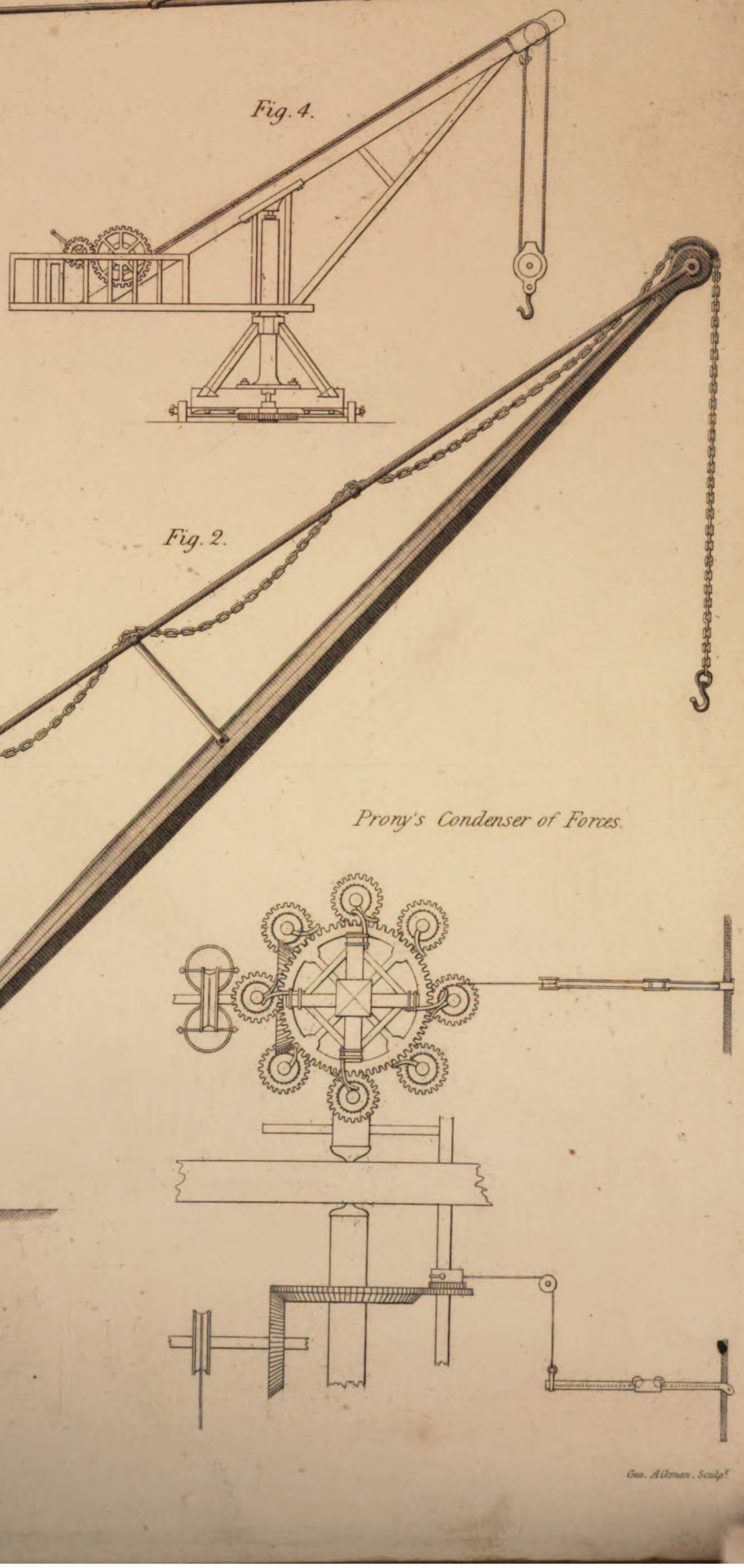

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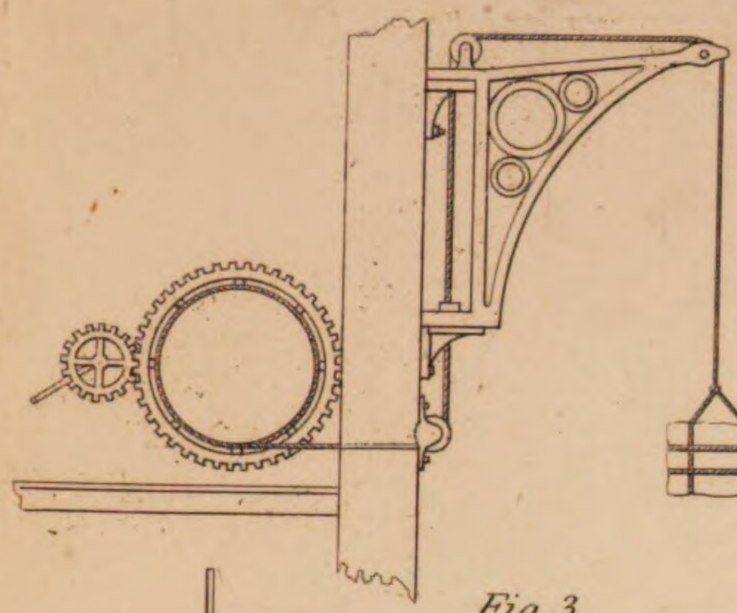

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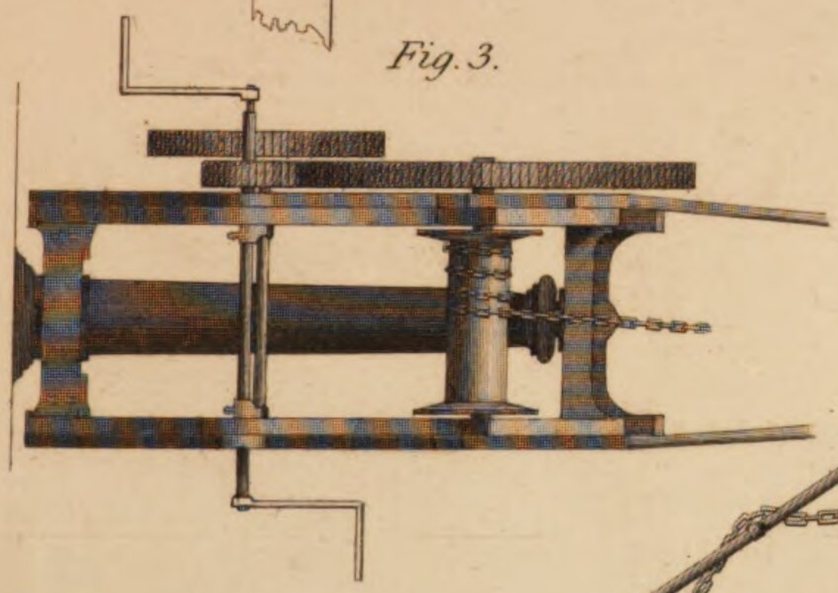

Prony's Condenser of Forces.

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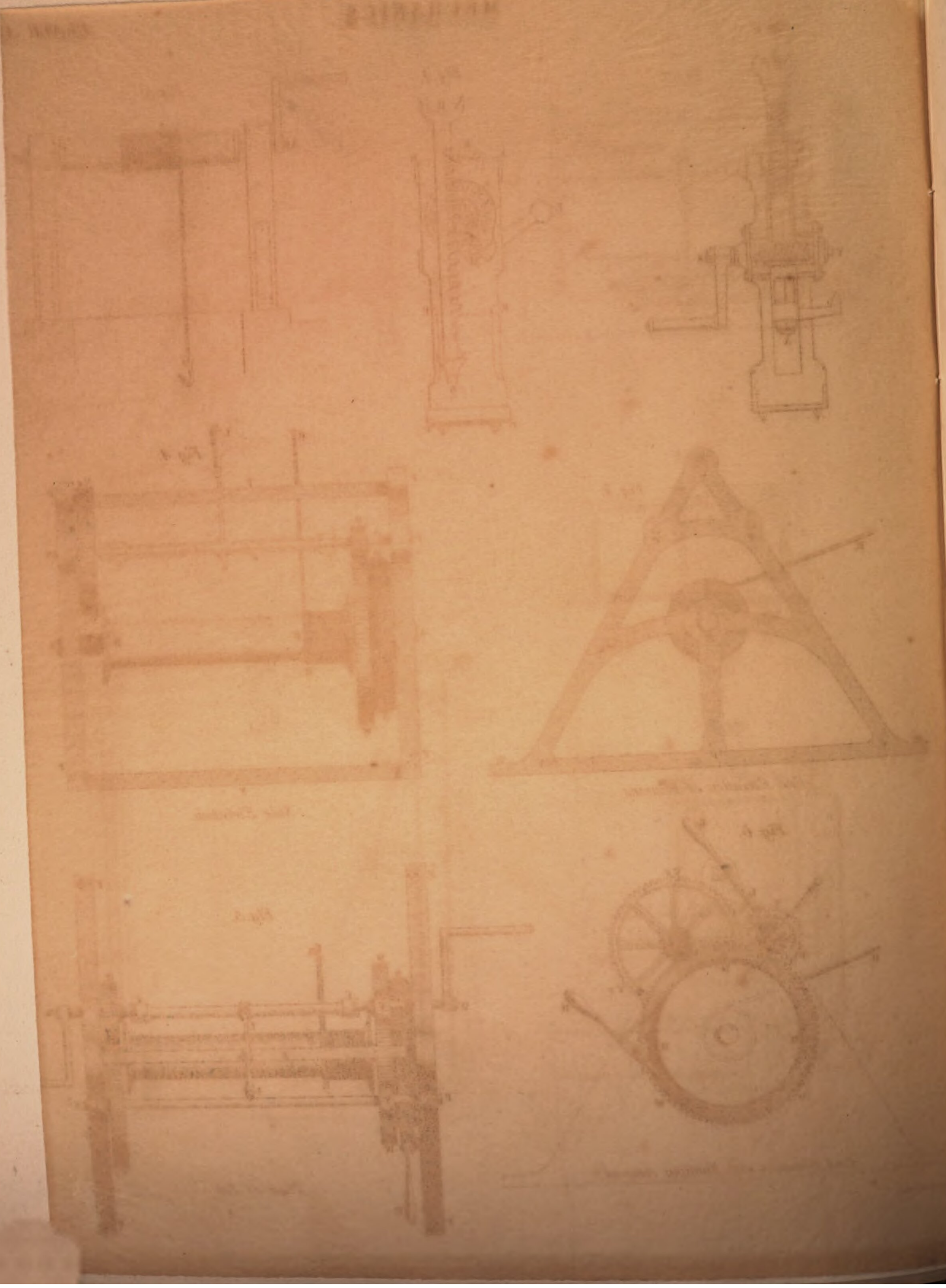

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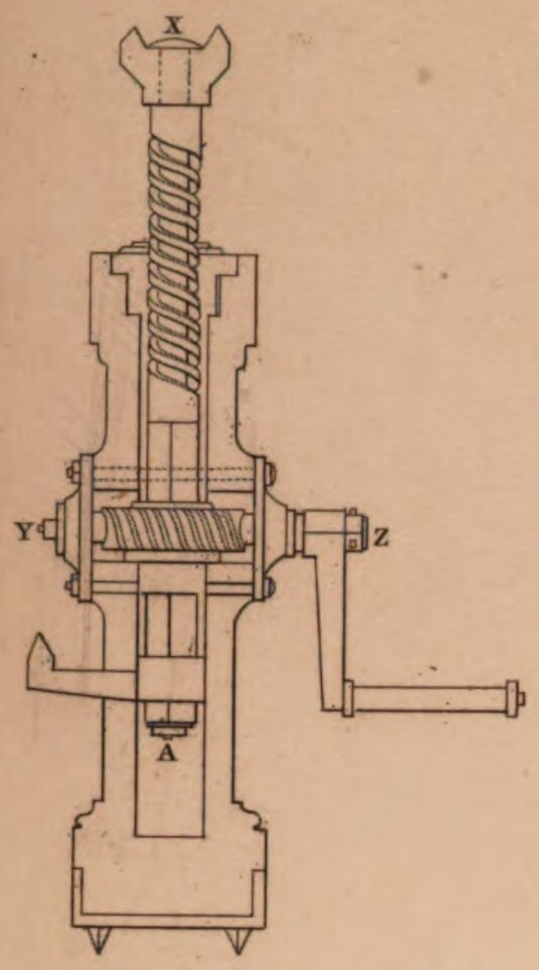


Fig. 1.

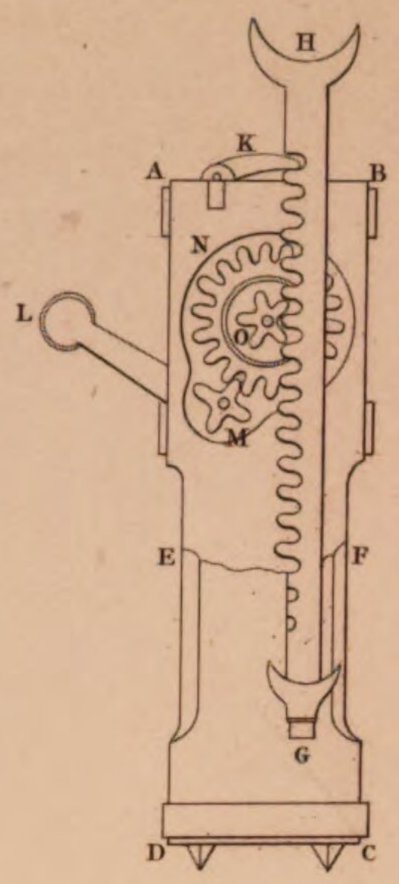


Fig. 3.

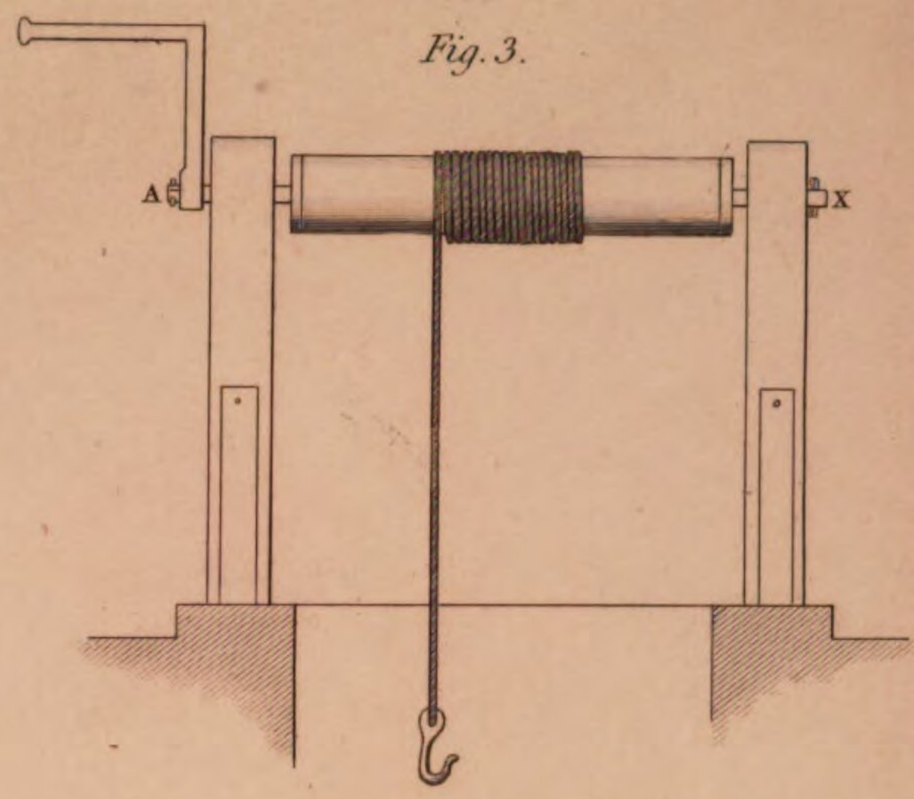
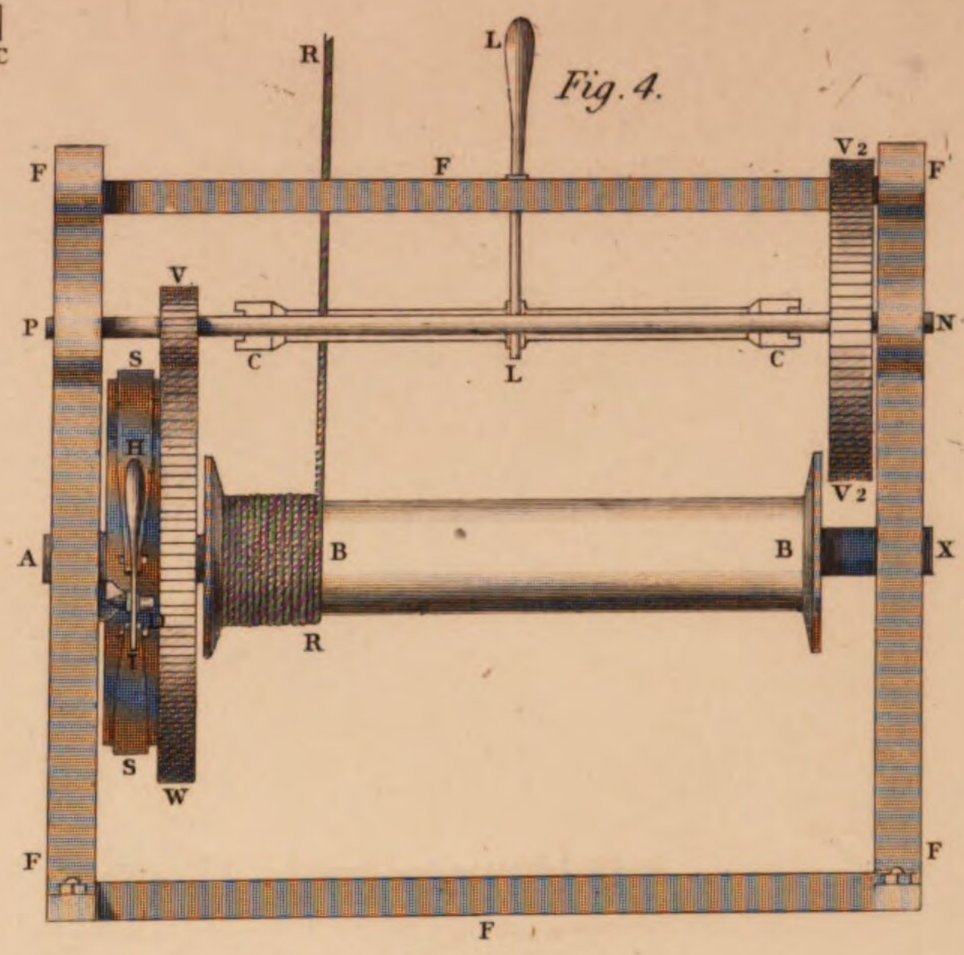
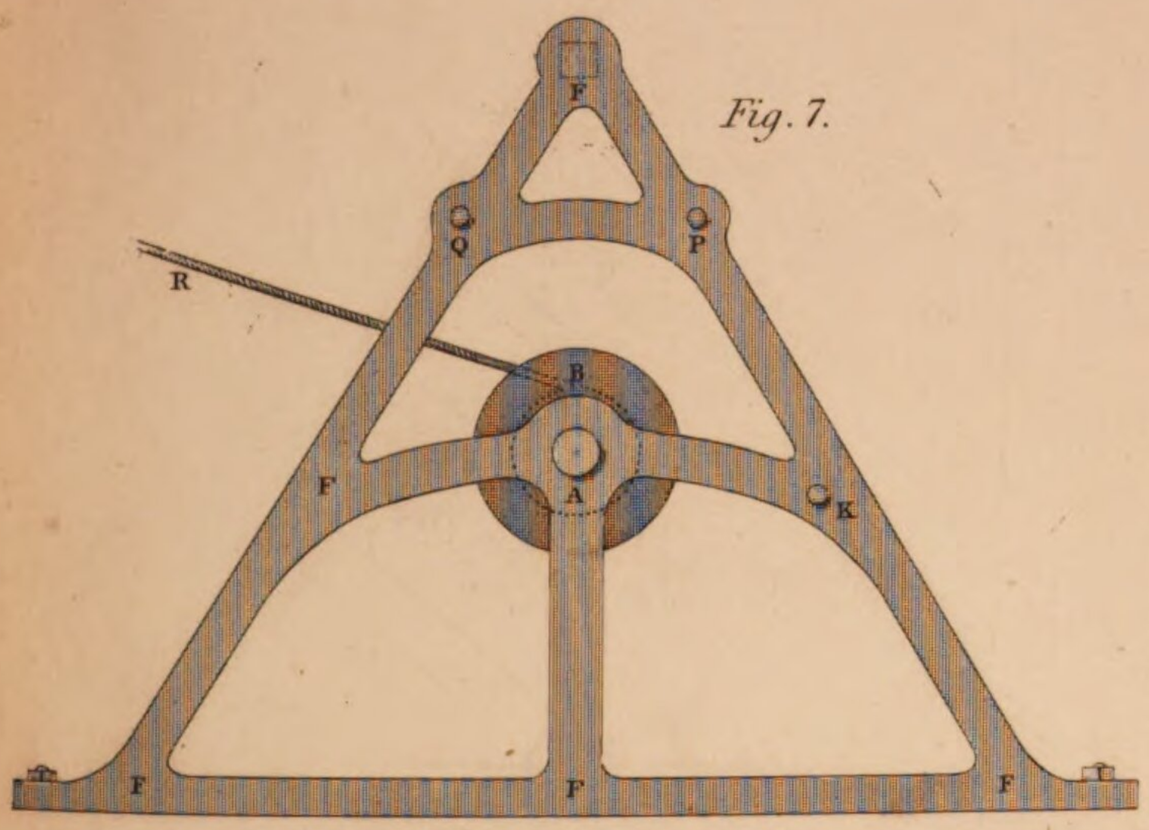


Fig. 4.



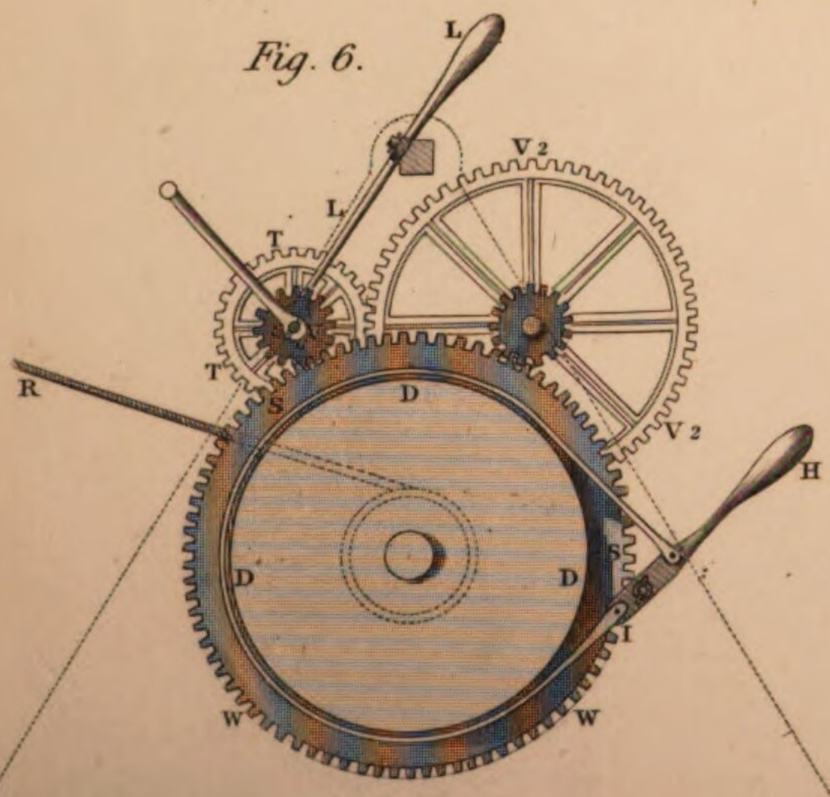
Side Elevation.

Fig. 7.



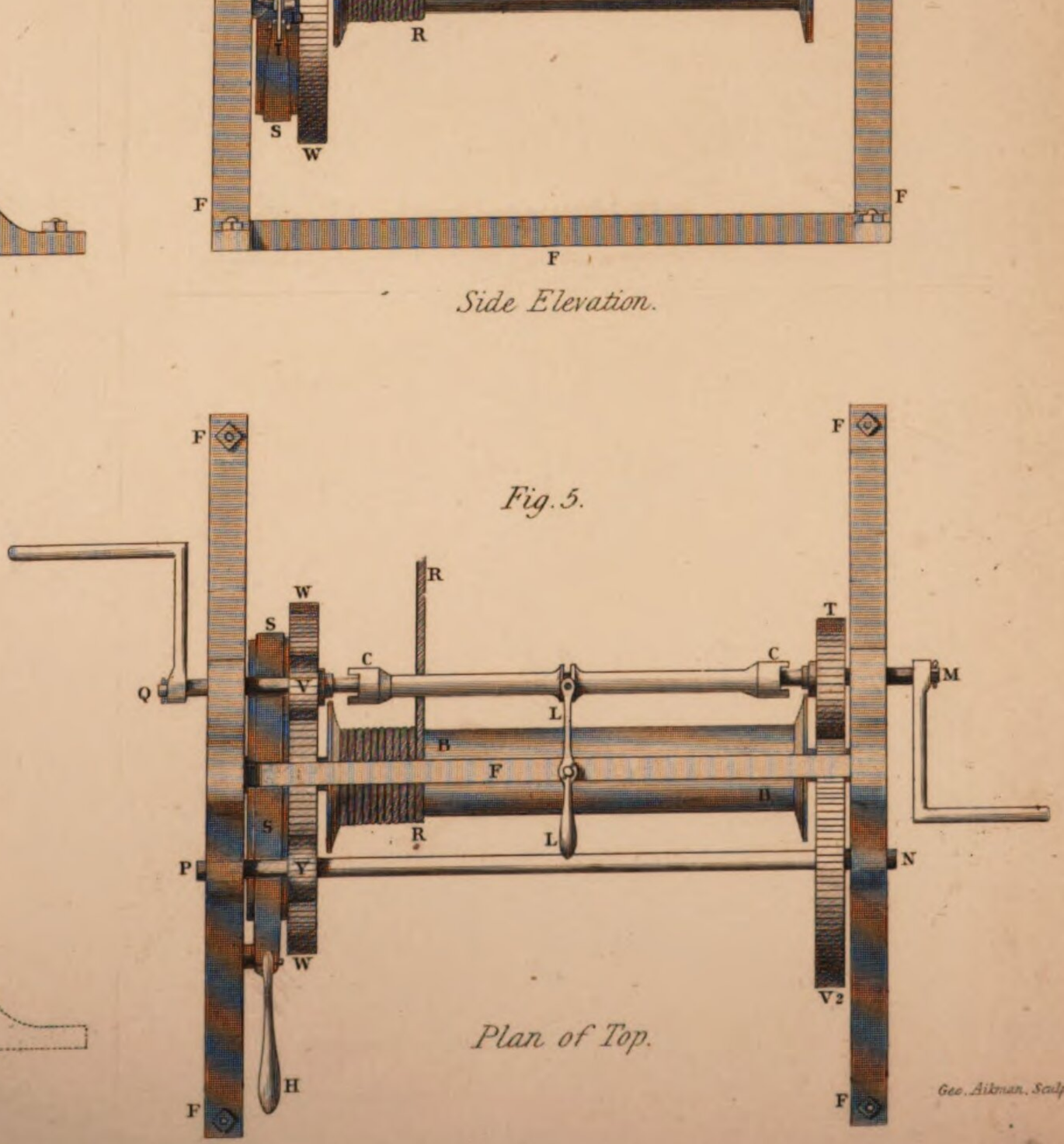
End Elevation of Framing.

Fig. 6.



End Elevation with Framing removed.

Fig. 5.



Plan of Top.

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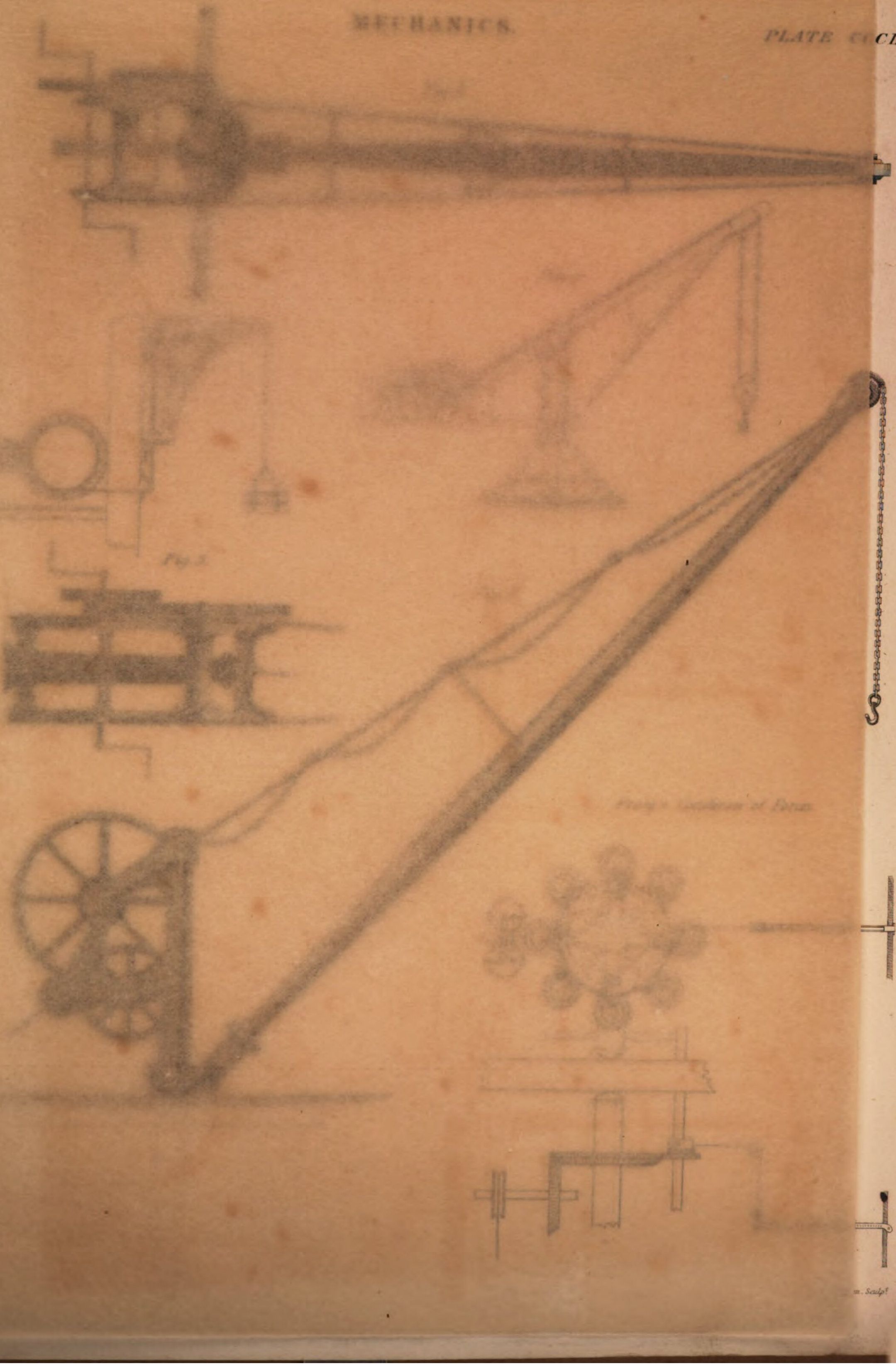
Gee. Aikman. Sculp.t



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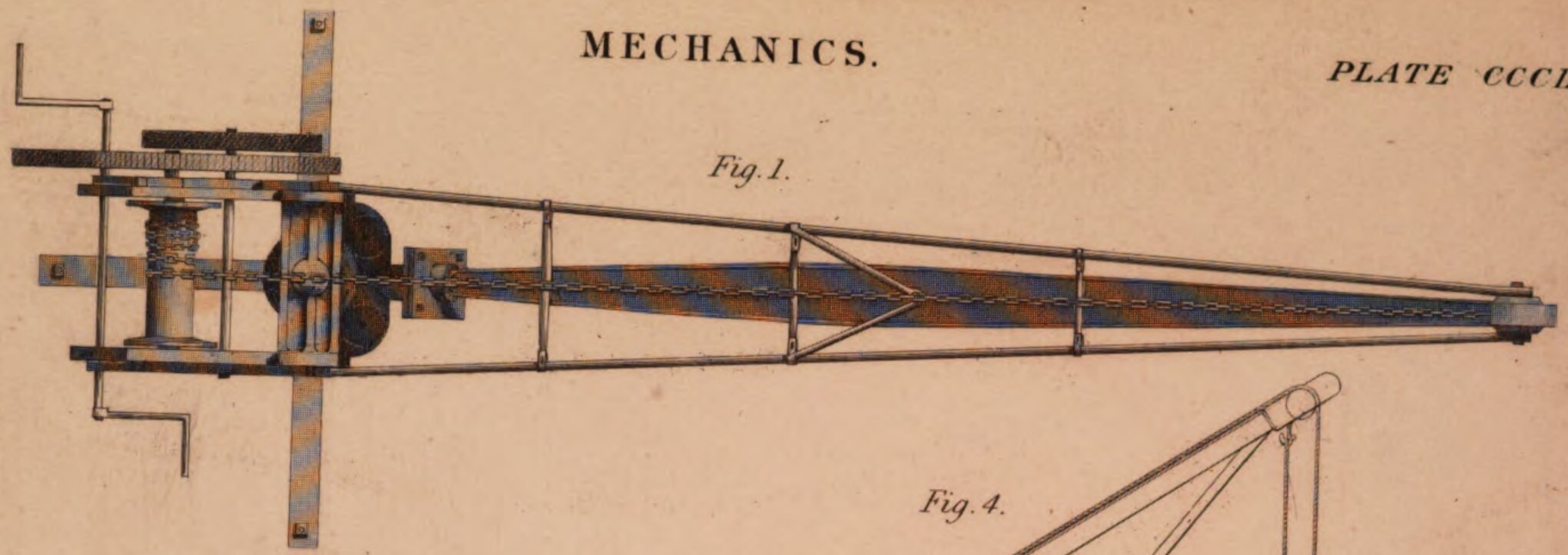

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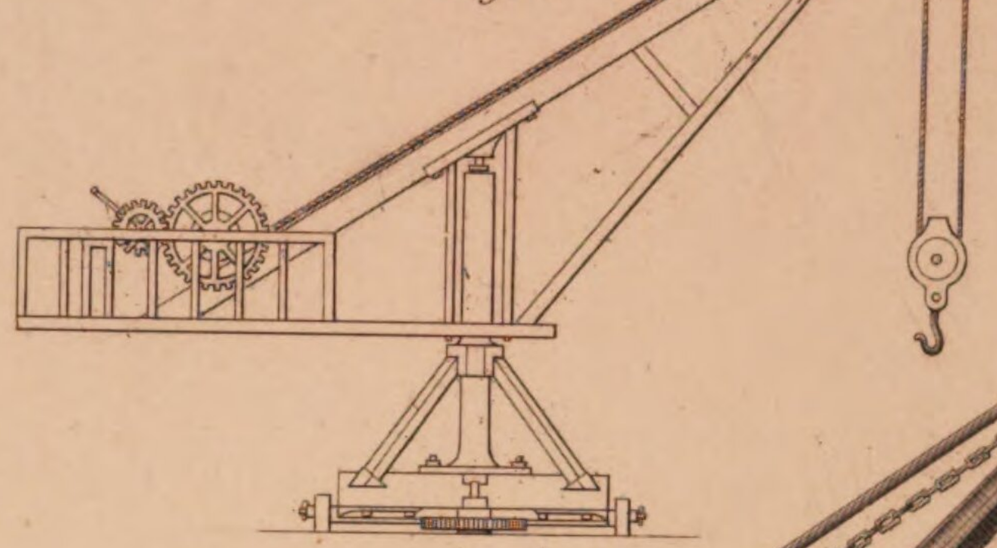

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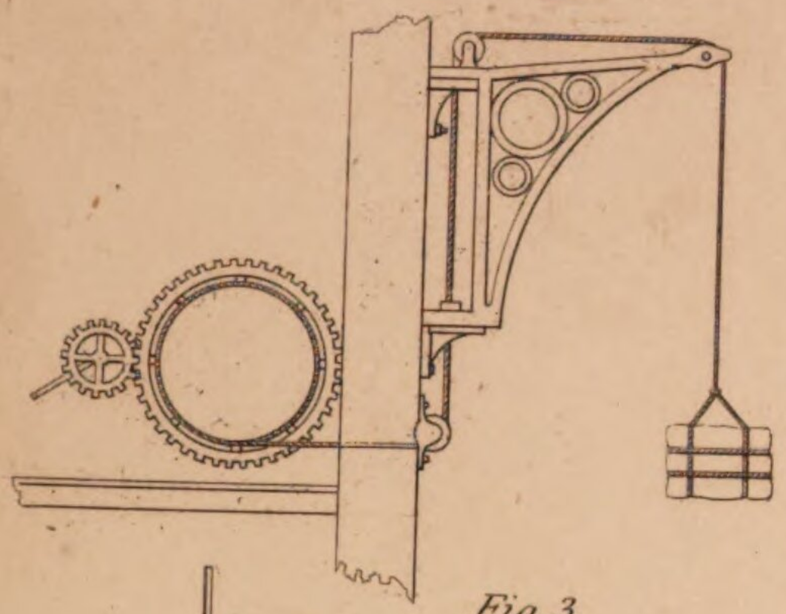

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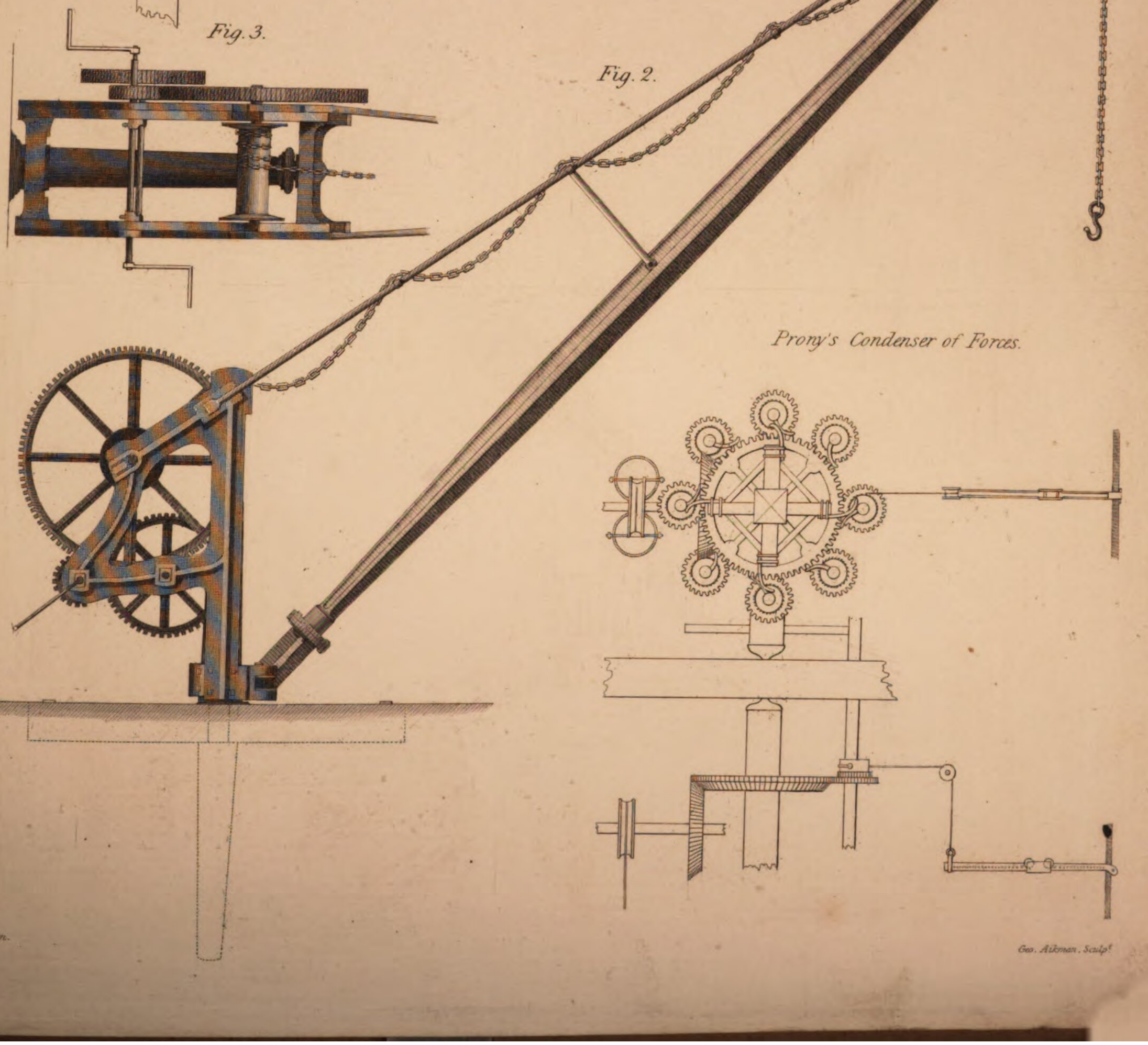

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